INSTITUTION

OF

MECHANICAL ENGINEERS.

PROCEEDINGS.

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1856.

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INDEX.

PAGE.
Annual Report 1
Address of the President 125
Agricultural Purposes, Application of Steam Power to, by W. Waller
  I. Agricultural Engines 80
  II. Barn Machinery 266
Air Engine, Compressed, at Govan Colliery, by C. Randolph 145
Boiler, Stationary, by J. Stephen 213
Buffing and Drawing Apparatus, Central, by E. D. Chattaway 173
Condenser, Surface, by J. P. Joule 185
Corn Mill Machinery, by A. White 140
Dredging Ladder, by M. Scott 217
Drilling and Grooving Machine, Double Traversing, by T. Forsyth 108
Expansion Valve, Double Slide, by F. W. Wymer 58
Fan, Ventilating, at Abercarn Collieries, by E. Rogers 251
File Cutting Machine, by R. C. Ross 226
Foundry Hoist and Cupola, by J. Fernie 49
Foundry, Iron Construction of, and Pipe Moulding, by J. Downie 165
Grooved-Surface Frictional Gearing, by J. Robertson 202
Iron Ships, New Construction of, for War Purposes, by P. Conti 221
Locomotive Boiler, by A. Allan 233
Locomotive Boiler, by W. Neilson 236
Marine Engine, Direct-Action, for Screw Propulsion, by E. Hunt 159
Pile Driver, Steam, by R. Morrison 287
Preservation of Timber, by J. Reid, Jun. 196
Pumping Engines, at Wolverhampton Water Works, by H. Marten 7
Railway Crossing, by H. Woodhouse 35
Rivetting Machine, Steam, by R. Harvey 134
Safety Valve, by J. Ramsbottom 37
Steam Dash Wheel for Bleaching, by J. Wallace, Jun. 239
Subjects for Papers 43
Sugar Evaporator, by R. Harvey 179
Valve Motion, Straight Link, for Locomotive Engines, by A. Allan 70
Valve Packing, for Marine Engines, by C. Beyer 61
Water Meter, by C. W. Siemens 113
Water Meter, by W. Gorman 242
Water Meter, Piston, by T. Kennedy 151
Wood Bearings, for Screw Propeller Shafts, by J. Penn 24

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LIST OF MEMBERS,

WITH YEAR OF ELECTION.

1856.

1848. Adams, William Alexander, Midland Works, Birmingham.

1851. Addison, John, 3, Delahay Street, Westminster, S.W

1853. Adkins, Francis, Heath Lead Works, near Birmingham.

1847. Allan, Alexander, Scottish Central Railway, Perth.

1856. Allen, Edward Ellis, 376, Strand, London, W.C.

1856. Allen, James, Cambridge Street Works, Manchester.

1856. Anderson, John, Chief Inspector of Machinery, Royal Arsenal, Woolwich, S.E.

1856. Anderson, William, Messrs. Courtney and Stephens, Blackall Place Iron Works, Dublin.

1848. Ashbury, John, Railway Carriage and Wheel Manufactory, Openshaw, near Manchester.

1848. Bagnall, William, Gold's Hill Iron Works, Westbromwich.

1848. Baker, William, London and North Western Railway, Euston Station, London, N.W.

1847. Barwell, William Harrison, Eagle Foundry, Northampton.

1851. Beasley, Joseph, District Iron Works, Smethwick.

1848. Beattie, Joseph, London and South Western Railway, Locomotive Department, Nine Elms, London, S.

1854. Bennett, Peter Duckworth, Spon Lane Foundry, Westbromwich.

1847. Beyer, Charles, Messrs. Beyer, Peacock, and Co., Gorton, near Manchester.

1847. Birley, Henry, Haigh Foundry, near Wigan.

1856. Blackburn, Isaac, Manor House Works, Long Eaton, near Derby.

1851. Blackwell, Samuel Holden, Russell's Hall Iron Works, near Dudley.

1847. Bovill, George Hinton, Messrs. Swayne and Bovill, 19, Abchurch Lane, London, E. C.

1854. Bragge, William, Imperial Petropolis Railway, Rio Janeiro.

1854. Bramwell, Frederick Joseph, 29, New Bridge Street, Blackfriars, London, E.C.

1856. Bray, Edwin, New Dock Iron Works, Leeds.

1848. Broad, Robert, Horseley Iron Works, near Tipton.

1852. Brogden, Henry, Ulverstone, Cumberland.

1847. Brown, James, Messrs. James Watt and Co., Soho Foundry, near Birmingham.

1850. Brown, John, Atlas Steel Works, Sheffield.
1855. Brown, John, Mining Engineer, Barnsley, Yorkshire.
1856. Brown, John, Mining Engineer, Bank Top, Darlington.
1853. Brown, Ralph, Patent Shaft Works, Wednesbury.
1856. Bunning, Theophilus Wood, Ouseburn Engine Works, Newcastle-on-Tyne.
1856. Butler, Ambrose Edmund, Kirkstall Forge, Leeds.

1847. Cabry, Thomas, North Eastern Railway, York.
1847. Cammell, Charles, Cyclops Steel Works, Sheffield.
1856. Carrett, William Elliott, Sun Foundry, Leeds.
1849. Chamberlain, Humphrey, Clerkenleap, Kempsey, near Worcester.
1852. Chellingworth, Thomas T., 105, Great Charles Street, Birmingham.
1854. Clark, Daniel Kinnear, 11, Adam Street, Adelphi, London, W.C.
1847. Clift, John Edward, Birmingham and Staffordshire Gas Works, Adderley Street, Birmingham.
1847. Cochrane, Alexander Brodie, Woodside Iron Works, near Dudley.
1854. Cochrane, John, Woodside Iron Works, near Dudley.
1847. Coke, Richard George, Ankerbold, near Chesterfield.
1853. Cooper, Samuel Thomas, Leeds Forge, Leeds.
1848. Corry, Edward, 8, New Broad Street, London, E.C.
1849. Cowper, Charles, 20, Southampton Buildings, Chancery Lane, London, W.C.
1847. Cowper, Edward Alfred, 35a, Great George Street, Westminster, S.W.
1852. Cox, Samuel H. F., Lingfield Lodge, East Grinstead, Sussex.
1853. Craig, William G., Manchester, Sheffield, and Lincolnshire Railway, Locomotive Department, Gorton, near Manchester.
1847. Crampton, Thomas Russell, 15, Buckingham Street, Adelphi, London, W.C.
1848. Croome, John, Elysian Cottage, New Cross, London, S.E.

1849. Dawes, George, Milton and Elsecar Iron Works, near Barnsley, Yorkshire.
1848. Dawson, Christopher H., Low Moor Iron Works, near Bradford, Yorkshire.
1854. Dodds, Thomas W., Holmes Engine Works, Rotherham.
1851. Downing, George, Selly Oak House, near Birmingham.
1847. Dubs, Henry, Gorton Foundry, near Manchester.
1856. Dudgeon, John, 151, Fenchurch Street, London, E.C.
1856. Dudgeon, William, 151, Fenchurch Street, London, E.C.
1854. Dunn, Thomas, Windsor Bridge Iron Works, Manchester.

1856. Eastwood, James, Railway Iron Works, Derby.
1848. Elder, David, Vulcan Foundry, Glasgow.
1849. Elwell, Edward, Jun., Wednesbury Forge, Wednesbury.
1853. England, George, Hatcham Iron Works, New Cross, Surrey, S.E.
1848. Everitt, George Allen, Kingston Metal Works, Bordesley, Birmingham.

1847. Fairbairn, William, F.R.S., The Polygon, Ardwick, Manchester
1852. Fairbairn, Thomas, Canal Street Works, Manchester.
1854. Fairbairn, George, Canal Street Works, Manchester.
1849. Fairbairn, William A., Canal Street Works, Manchester.
1856. Fay, Charles, Lancashire and Yorkshire Railway, Carriage Department, Manchester.
1847. Fenton, James, Low Moor Iron Works, near Bradford, Yorkshire.
1854. Fernie, John, Midland Railway, Locomotive Department, Derby.
1847. Fletcher, Edward, North Eastern Railway, Locomotive Department, Gateshead.
1849. Forsyth, John C., North Staffordshire Railway, Stoke-upon-Trent.
1849. Forsyth, Thomas, Messrs. Sharp, Stewart, and Co., Atlas Works, Manchester.
1847. Fothergill, Benjamin, 16, Queen's Chambers, 5, Market Street, Manchester.
1847. Fowler, John, 2, Queen Square Place, Westminster, S.W.
1847. Fox, Sir Charles, 8, New Street, Spring Gardens, London, S.W.
1853. Fraser, Joseph, Berkswell, near Coventry.
1856. Freeman, Joseph, 22, Cannon Street, London, E.C.
1852. Froude, William, Dartington, Totnes, Devonshire.

1847. Garland, William S., Messrs. James Watt and Co., Soho Foundry, near Birmingham.
1848. Gibbons, Benjamin, Hill Hampton House, near Stourport.
1856. Gilkes, Edgar, Tees Engine Works, Middlesboro-on-Tees.
1854. Goode, Benjamin W., St. Paul's Square, Birmingham.
1847. Goodfellow, Benjamin, Hyde Iron Works, Hyde, near Manchester.
1852. Gordon, Robert, Heaton Foundry, Stockport.
1848. Green, Charles, Tube Works, Leek Street, Birmingham.

1856. Harrison, George, Canada Works, Birkenhead.
1848. Hartree, William, Messrs. John Penn and Co., Marine Engineers, Greenwich, S.E.
1856. Hawksley, Thomas, 30, Great George Street, Westminster, S.W.
1848. Hawthorn, Robert, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
1848. Hawthorn, William, Messrs. R. and W. Hawthorn, Forth Banks, Newcastle-on-Tyne.
1853. Headly, James J., Eagle Works, Cambridge.
1847. Henderson, John, London Works, near Birmingham.
1847. Hennet, George, 24, Duke Street, Westminster, S.W.
1850. Henson, Henry H., 38, Parliament Street, Westminster, S.W.
1848. Hewitson, William Watson, Messrs. Kitson and Co., Airedale Foundry, Leeds.
1853. Hickman, George Haden, Bilston Brook Furnaces, Dudley.
1854. Hodgkin, John Eliot, Suffolk Works, Berkeley Street, Birmingham.
1852. Holcroft, James, Shut End, Brierley Hill, Worcestershire.
1848. Homersham, Samuel Collett, 19, Buckingham Street, Adelphi, London, W.C.
1856. Hopkinson, John, Messrs. Wren and Hopkinson, Altrincham Street, Manchester.

1851. Horton, Joshua, Etna Works, Smethwick.
1847. Howell, Joseph, Hawarden, near Chester.
1847. Hughes, John, 34, Great George Street, Westminster, S.W.
1847. Humphrys, Edward, Messrs. Humphrys, Tennant, and Dykes, Deptford Pier, London, S.E.
1856. Hunt, Thomas, London and North Western Railway, Locomotive Department, Crewe.

1850. Ikin, Jonathan Dickson, 2, Cannon Row, Westminster, S.W.

1847. Jackson, Peter Rothwell, Salford Rolling Mills, Manchester.
1856. James, Jabez, 28A, Broadwall, Stamford Street, Lambeth, London, S.
1848. Jee, Alfred Stanistreet, 6, John Street, Adelphi, London, W.C.
1855. Jeffcock, Parkin, Mining Engineer, 3, Stuart Terrace, Greenhill, Derby.
1856. Jeffreys, Edward, Shrewsbury and Hereford Railway, Locomotive Department, Shrewsbury.
1854. Jobson, John, Litchurch Works, near Derby.
1847. Jobson, Robert, Wordsley Works, near Dudley.
1847. Johnson, James, Great Northern Railway, Locomotive Department, Doncaster.
1848. Johnson, Richard William, The Laurels, Hagley Road, Birmingham.
1849. Johnson, William, 166, Buchanan Street, Glasgow.
1855. Johnson, William Beckett, St. George's Iron Works, Hulme, Manchester.
1847. Jones, Edward, Old Park Iron Works, Wednesbury.
1853. Joy, David, 5, Queen Square, Leeds.

1847. Kennedy, James, 59, Erskine Street, Liverpool.
1848. Kinmond, William L., Hamilton Steam Engine and Forge Works, Hamilton, Canada West.
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1847. Kirtley, Matthew, Midland Railway, Locomotive Department, Derby.
1848. Kitson, James, Airedale Foundry, Leeds.

1856. Laybourn, Richard, Monmouthshire Railway and Canal Company, Locomotive Department, Newport, Monmouthshire.
1856. Levick, Frederick, Cwm Celyn, Blaina, and Coalbrook Vale Iron Works, near Newport, Monmouthshire.
1848. Lewis, Benjamin, Stanley Street Works, Salford, Manchester.
1856. Linn, Alexander Grainger, 121, Upper Parliament Street, Liverpool.
1854. Lloyd, George Braithwaite, Jun., Tube Works, Berkeley Street, Birmingham.
1847. Lloyd, Sampson, Old Park Iron Works, Wednesbury.
1852. Lloyd, Samuel, Jun., Old Park Iron Works, Wednesbury.

1856. Longridge, Robert Bewick, 11, Winfield Terrace, Old Trafford, Manchester.
1854. Lynde, James Gascoigne, 7, Great Queen Street, Westminster, S.W.

1848. Macgregor, Walter F., Vauxhall Foundry, Liverpool.
1856. Mackay, John, Drogheda Iron Works, Drogheda.
1856. Markham, Charles, Midland Railway, Locomotive Department, Derby.
1848. Marshall, Edwin, Britannia Carriage Works, Birmingham.
1847. Marshall, William Prime, 81, Newhall Street, Birmingham.
1853. Marten, Henry, 19, Darlington Street, Wolverhampton.
1854. Martineau, Francis Edgar, Globe Works, Cliveland Street, Birmingham.
1853. Mathews, William, Corbyn's Hall Iron Works, near Dudley.
1848. Matthew, John, Messrs. John Penn and Co., Marine Engineers, Greenwich, S. E.
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1847. McClean, John Robinson, 17, Great George Street, Westminster, S.W.
1847. McConnell, James Edward, London and North Western Railway, Locomotive Department, Wolverton.
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1853. Miller, George M., Great Southern and Western Railway, Dublin.
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1856. Mitchell, Charles, Low Walker Iron Ship Building Works, Newcastle-on-Tyne.
1849. Morrison, Robert, Ouseburn Engine Works, Newcastle-on-Tyne.
1856. Muntz, George Henri Marc, 3, Lansdowne Terrace, Handsworth, near Birmingham.

1848. Napier, John, Vulcan Foundry, Glasgow.
1856. Napier, Robert, Vulcan Foundry, Glasgow.
1856. Newall, James, East Lancashire Railway, Carriage Department, Bury, Lancashire.
1851. Nixon, Charles, 26, Great George Street, Westminster, S.W.
1850. Norris, Richard Stuart, London and North Western Railway, Engineer's Office, Liverpool.

1847. Owen, William, Messrs. Sandford and Owen, Phœnix Works, Rotherham.

1847. Paton, William, Edinburgh and Glasgow Railway, Locomotive Department, Cowlairs, Glasgow.
1853. Payne, Edward J., 1, Bennett's Hill, Birmingham.
1847. Peacock, Richard, Messrs. Beyer, Peacock, and Co., Gorton, near Manchester.
1848. Pearson, John, Liver Iron Works, Boundary Street, Liverpool.
1848. Penn, John, Messrs. John Penn and Co., Marine Engineers, Greenwich, S.E.
1856. Perring, John Shae, Resident Engineer, East Lancashire Railway, Bury, Lancashire.
1856. Piggott, George, Birmingham Heath Boiler Works, Birmingham.
1854. Pilkington, Richard, Jun., St. Helen's Foundry, St. Helen's.

1852. Plant, Reuben, Pensnett Collieries, Brierley Hill, Worcestershire.
1856. Pollard, John, Machine and Tool Maker, Leeds.
1852. Porter, John Henderson, Iron Roofing Works, Gas Street, Birmingham.
1856. Preston, Francis, Ardwick Spindle Works, Manchester.
1848. Preston, Robert B., 10, Abercromby Square, Liverpool.
1855. Prideaux, Thomas Symes, 32, Charing Cross, London, S.W.

1847. Ramsbottom, John, London and North Western Railway, Locomotive Department, Longsight, Manchester.
1856. Reeves, Charles, Toledo Works, Charlotte Street, Birmingham.
1856. Richards, Josiah, Ebbw Vale Iron Works, near Newport, Monmouthshire.
1847. Richards, Thomas, 30, Hill Morton Road, Rugby.
1848. Robertson, Henry, Shrewsbury and Chester Railway, Shrewsbury.
1847. Robinson, Henry, 8, Chandos Street, Cavendish Square, London, W.
1847. Roche, David M., East Indian Railway, Howrah, Calcutta.
1852. Rofe, Henry, Birmingham Water Works, Paradise Street, Birmingham.
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1851. Rolinson, Thomas, Wellington Road, Dudley.
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1847. Russell, John Scott, F.R.S., 37, Great George Street, Westminster, S.W.

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1850. Shanks, Andrew, 6, Robert Street, Adelphi, London, W.C.
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1847. Sinclair, Robert, Eastern Counties Railway, Locomotive Department, Stratford, London, E.
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1854. Smith, George, Wellington Road, Dudley.
1847. Smith, Henry, Spring Hill Works, Birmingham.
1848. Spencer, Joseph, Bilston Foundry, Bilston.
1853. Spencer, Thomas, Oaken, Wolverhampton.

1854. Spencer, Thomas, Newburn Steel Works, Newcastle-on-Tyne.
1855. Stenson, William, Jun., Whitwick Collieries, near Ashby-de-la-Zouch.
1851. Stewart, John, Blackwall Iron Works, Russell Street, Blackwall, London, E.

1848. Thompson, Isaac, Messrs. Kitson and Co., Airedale Foundry, Leeds.
1851. Thompson, James, Pin Mill, Ardwick, Manchester.
1852. Thomson, George, Crookhay Furnaces, Westbromwich.
1848. Thornton, Robert, 54, North Bridge, Edinburgh.
1847. Thornton, Samuel, Bradford Street, Birmingham.
1849. Tiernay, James B., Horseley Iron Works, near Tipton.
1856. Tosh, George, Maryport and Carlisle Railway, Locomotive Department, Maryport.
1856. Truss, Thomas, Shrewsbury and Chester Railway, Carriage Department, Chester.
1849. Turton, Thomas Burdett, Sheaf Works, Sheffield.
1856. Tyler, Capt. Henry Wheetley, R.E., Railway Department, Board of Trade, Whitehall, London, S.W.

1856. Vernon, John, Iron Ship Building Yard, Brunswick Dock, Liverpool.

1856. Waddington, John, New Dock Iron Works, Leeds.
1856. Waddington, Thomas, New Dock Iron Works, Leeds.
1847. Walker, Thomas, Patent Shaft Works, Wednesbury.
1856. Wardle, Charles Wetherell, Railway Foundry, Leeds.
1852. Warham, John R., Iron Works, Burton-on-Trent.
1847. Weallens, William, Messrs. R. Stephenson and Co., South Street, Newcastle-on-Tyne.
1856. Wheeldon, Frederick R., Highfields Engine Works, Bilston.
1856. Whitehouse, Henry Bickerton, Deepfields Iron Works, near Bilston.
1847. Whitworth, Joseph, Chorlton Street, Manchester.
1847. Williams, Richard, Patent Shaft Works, Wednesbury.
1850. Williams, Walter, Jun., Albion Iron Works, Westbromwich.
1856. Wilson, Edward, Oxford, Worcester, and Wolverhampton Railway, Worcester.
1852. Wilson, Joseph W., Neithrep, Banbury.
1848. Wingate, Thomas, Whiteinch Foundry, Partick, near Glasgow.
1848. Woodhouse, Henry, London and North Western Railway, Stafford.
1851. Woodhouse, John Thomas, Midland Road, Derby.
1848. Wright, Henry, Saltley Works, Birmingham.
1848. Wright, Joseph, Saltley Works, Birmingham.
1853. Wymer, Francis W., 7, Hewgill Terrace, Newcastle-on-Tyne.

1856. Yarrow, Thomas, Aberdeen and Scottish Midland Junction Railway, Locomotive Department, Arbroath.
1856. Young, John, Railway Foundry, Leeds.

LIFE MEMBERS.

1853. Maudslay, Henry, 4, Cheltenham Place, Lambeth, London, S.
1847. Stephenson, Robert, M.P., 24, Great George Street, Westminster, S.W.

HONORARY MEMBERS.

1848. Alston, William Charles, Leek Street, Birmingham.
1848. Branson, George, Belmont Row, Birmingham.
1851. Clare, Thomas Deykin, Midland Railway Station, Birmingham.
1848. Crosby, Samuel, Leek Street, Birmingham.
1850. Gwyther, Edwin, Belmont Row, Birmingham.
1848. Heane, Henry, Newport, Shropshire.
1854. Knight, George, 22, Parliament Street, Westminster, S.W.
1856. Marshall, John, Low Moor Iron Works, near Bradford, Yorkshire.
1856. Moss, Henry E., 2, Rumford Place, Liverpool.
1848. Peto, Sir Samuel Morton, Bart., 9, Great George Street, Westminster, S.W.
1856. Pettifor, Joseph, Midland Railway, Derby.
1856. Singleton, William, Dock Street, Leeds.
1848. Warden, William Marston, Edgbaston Street, Birmingham.
1855. Wills, William Ridout, Waterloo Street, Birmingham.
1854. Woolley, Rev. Joseph, LL.D., Royal Dockyard, Portsmouth.

HONORARY LIFE MEMBERS.

1849. Hodgkinson, Eaton, F.R.S., 44, Drayton Grove, Brompton, London, S.W.
1848. MacGregor, James, National Club, Whitehall Place, London, S.W.

GRADUATES.

1850. Glydon, George, Spring Hill Works, Eyre Street, Birmingham.
1851. Potts, J. Thorpe, Tube Works, Gas Street, Birmingham.
1856. Waller, William, Messrs. Clayton, Shuttleworth, and Co., Stamp End Works, Lincoln.

WATER WORKS ENGINES

Plate 1

Fig 1
Tettenhall
Pumping Engines

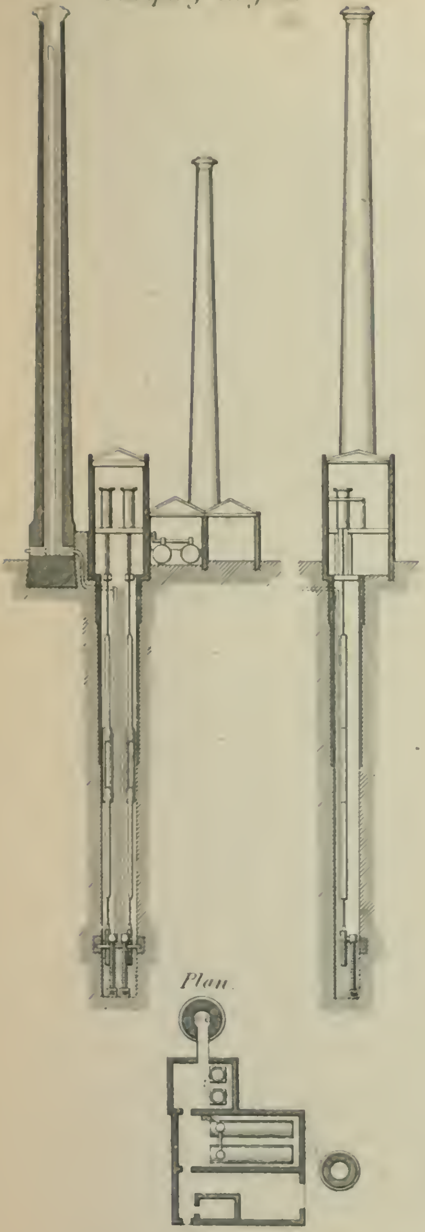
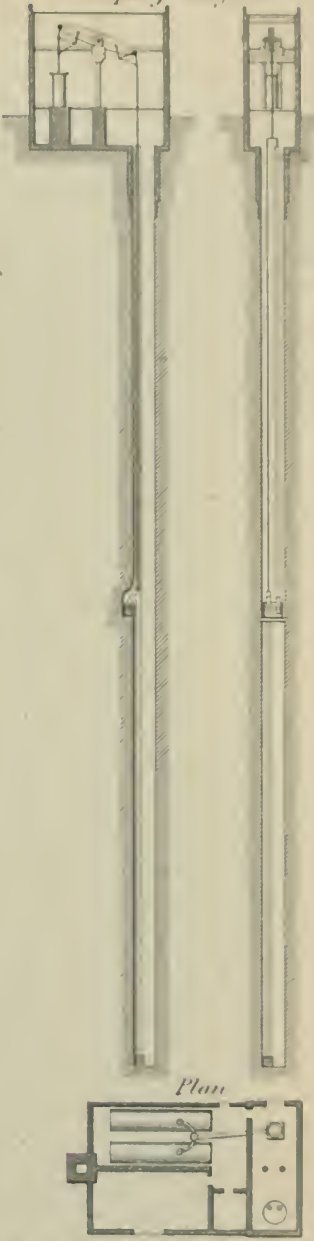


Fig 9
Goldthorn Hill
Pumping Engine



Scale $^1/_{720}$th 0 5 10 20 30 40 50 60 70 80 90 100 Feet.

(Proceedings Inst. M. E. 1856. Page 7.)

WATER WORKS ENGINES

Plate 4.

Tettenhall Pumping Engines

Fig. 2.

Side Elevation

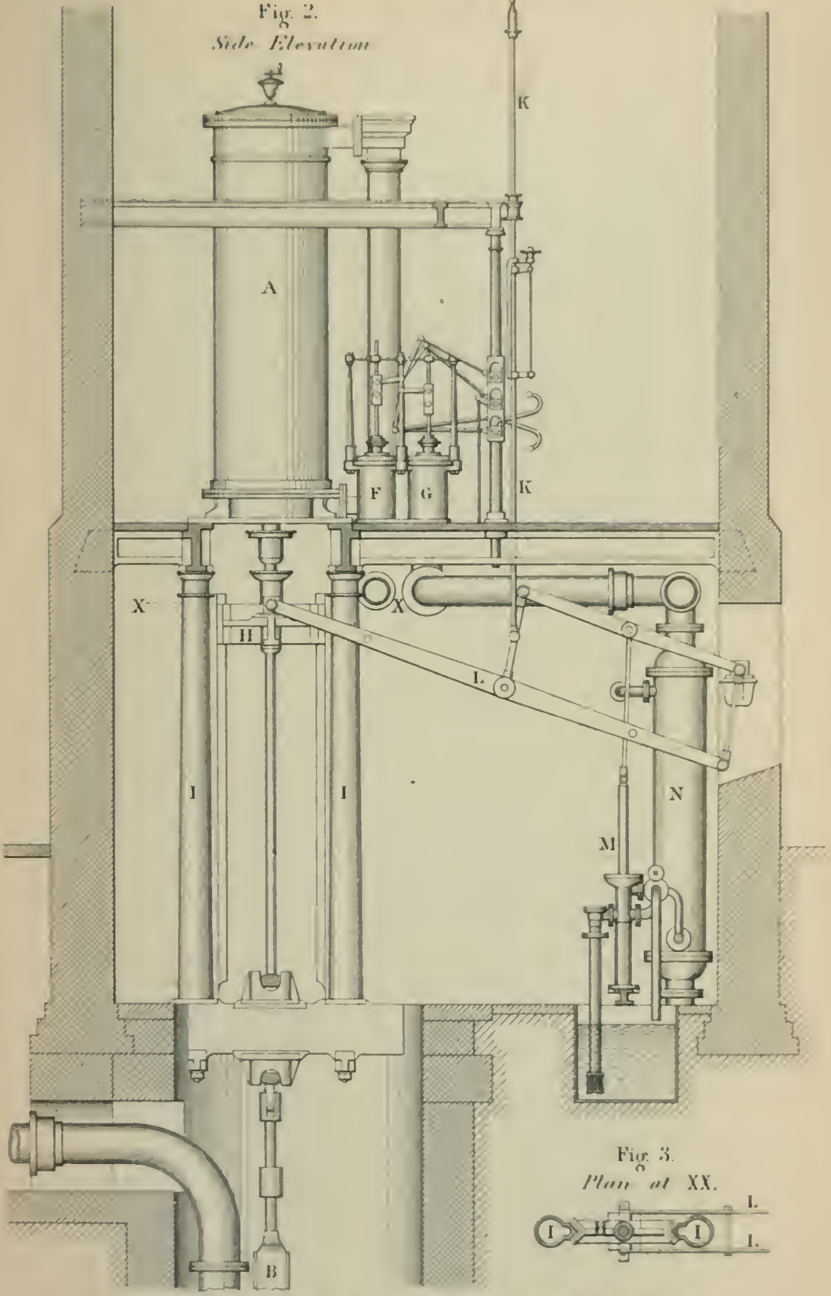


Fig. 3.

Plan at XX.

Scale 1/72nd *Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet*

(Proceedings Inst. M.E. 1856. Page 7.)

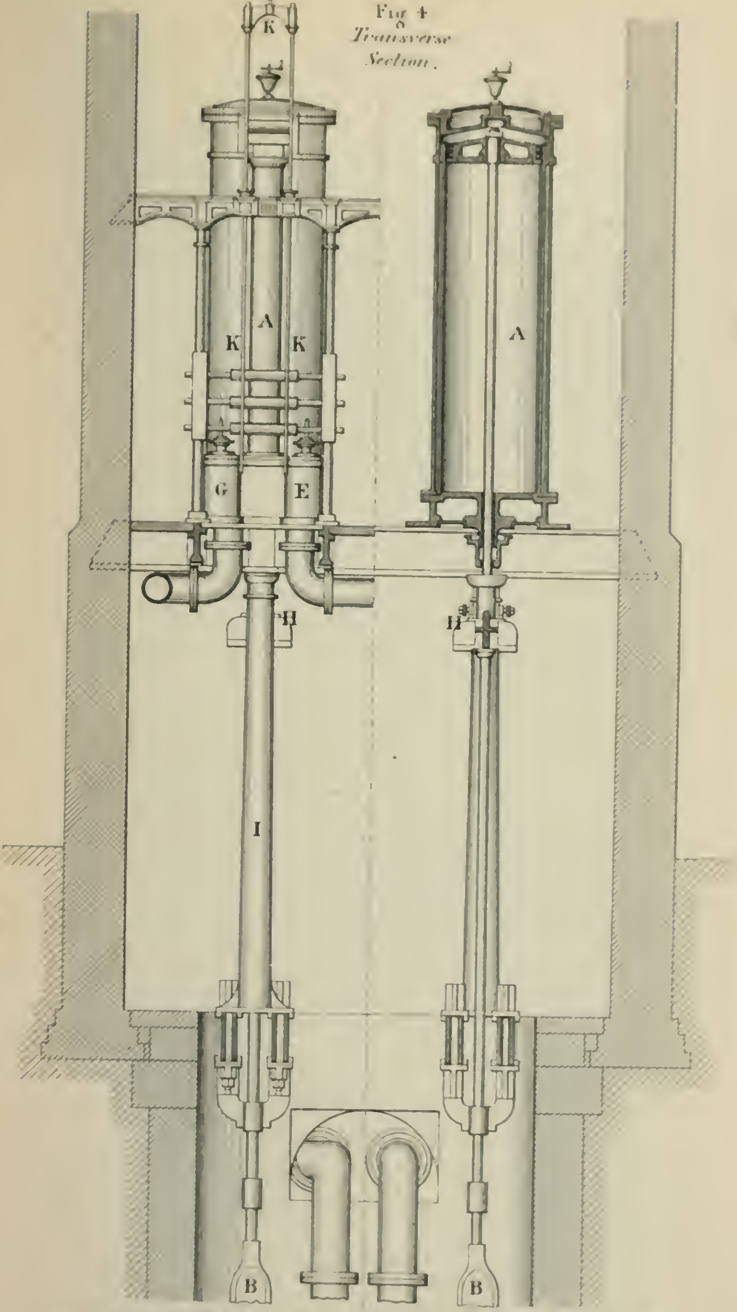
WATER WORKS ENGINES

Tettenhall Pumping Engines

Plate 4.

Fig 4

Transverse Section.



Scale 1/72nd *Ins 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet*

(Proceedings Inst. M. E. 1856. Page 7.)

WATER WORKS ENGINES.

Tettenhall Pumping Engines.

Fig. 5. Elevation of Pumps

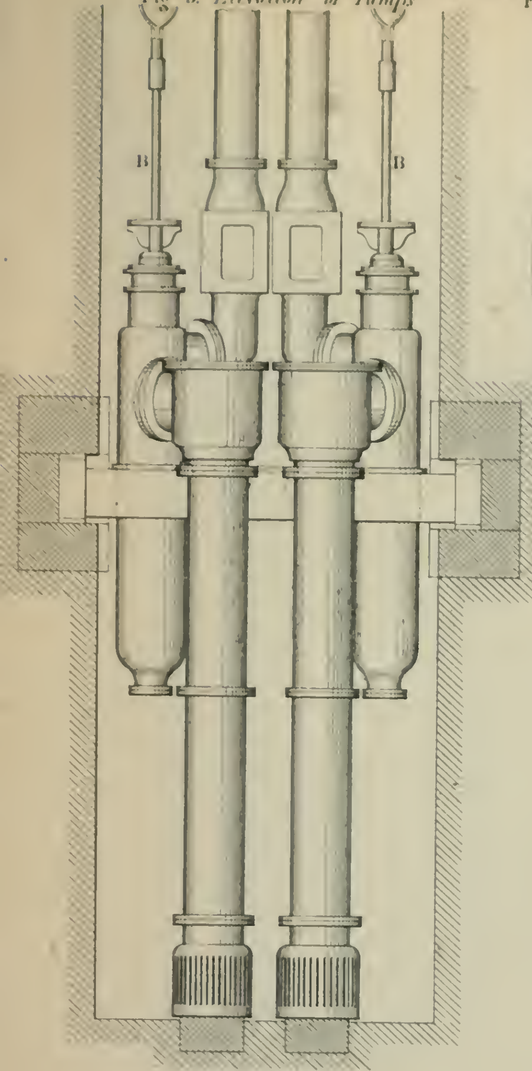
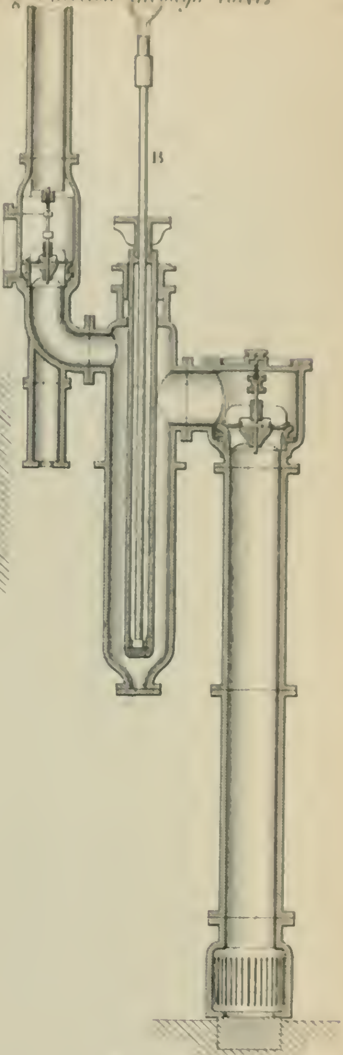


Fig. 6. Section through Valves



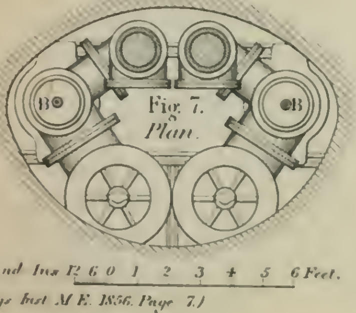
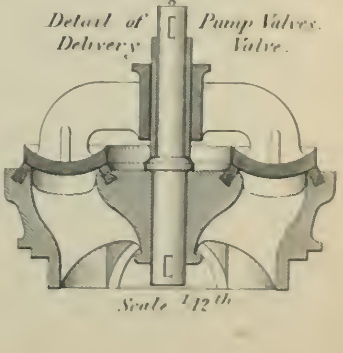


Fig. 7.
Plan.

Fig. 8

Detail of Pump Valves.
Delivery Valve.



Scale 1/72nd Ins 12 6 0 1 2 3 4 5 6 Feet.

(Proceedings Inst. M.E. 1856. Page 7.)

Scale 1/12th

WATER WORKS ENGINES

Goldthorn Hill
Pumping Engine
Regulating Valve
for Reservoirs

Fig. 10.

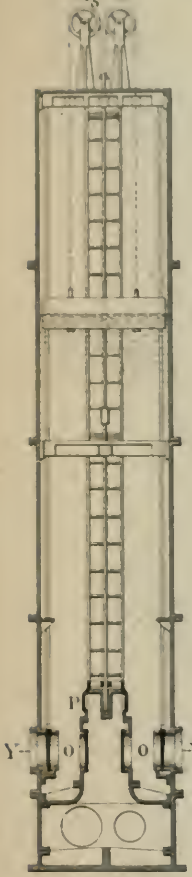


Fig. 11.

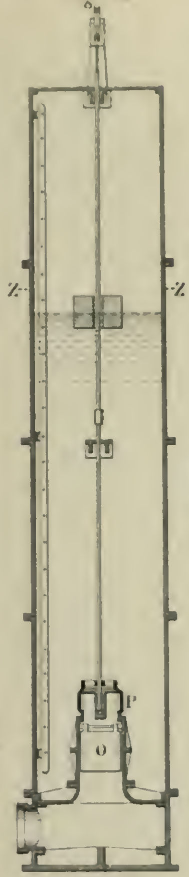


Fig. 12.
Plan at YY

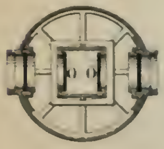
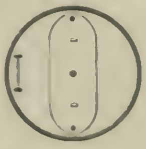


Fig. 13.
Plan at ZZ

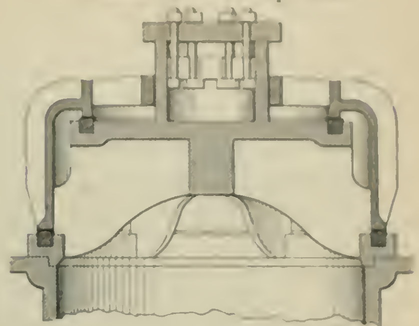


Scale 1/72nd

Ins 12 6 0 1 2 3 4 5 6 Feet

(Proceedings Inst. M.E. 1856 Page 7.)

Fig. 14.
Harvey and West's
Double-Beat Pump Valve



Scale 1/12th

Fig. 15.
Hosking's Valve.

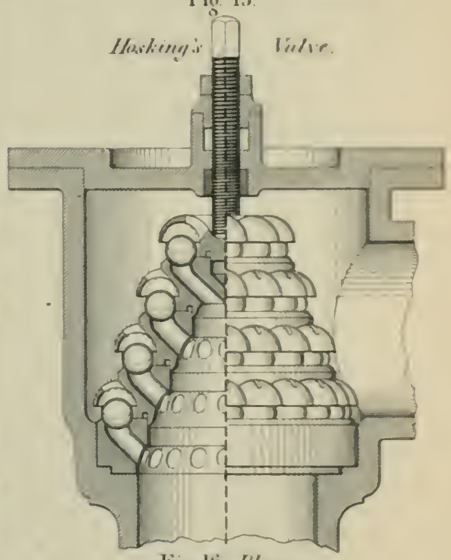
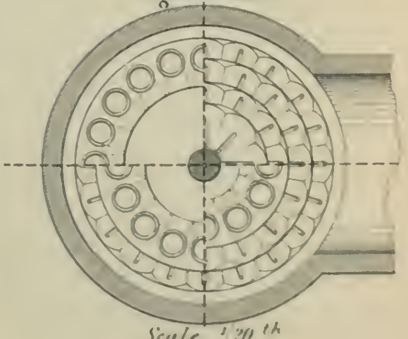


Fig. 16. *Plan.*



Scale 1/20th

WOOD BEARINGS.

Plate 46

Fig. 1.
Longitudinal Section

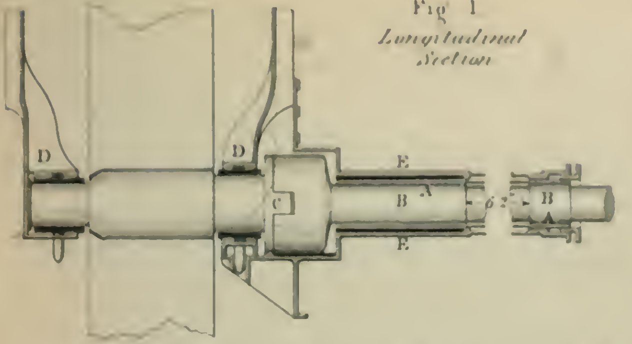
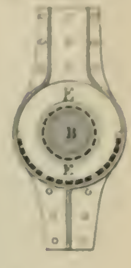
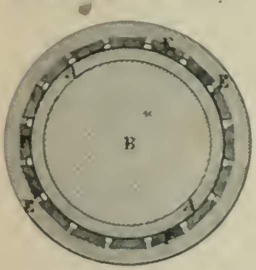


Fig. 2.
Transverse Section



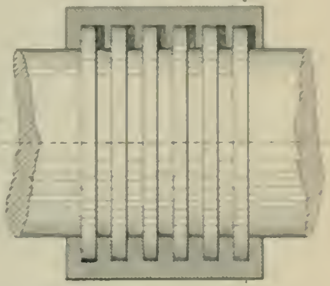
Scale 1/64th Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet

Fig. 3.
Transverse Section of Shaft and Bearing.



Scale 1/16th

Fig. 8.
Longitudinal Section of Thrust Bearing.



Apparatus used for Experiments
Fig. 4. *Transverse Section.*

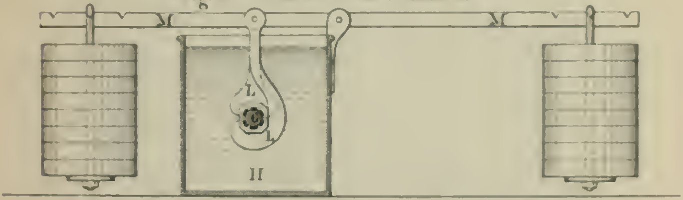
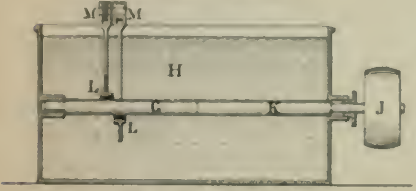


Fig. 5.
Longitudinal Section.



Pieces of Wood experimented upon.

Fig. 6. *Full Size.*

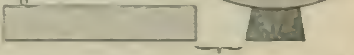
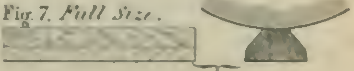


Fig. 7. *Full Size.*

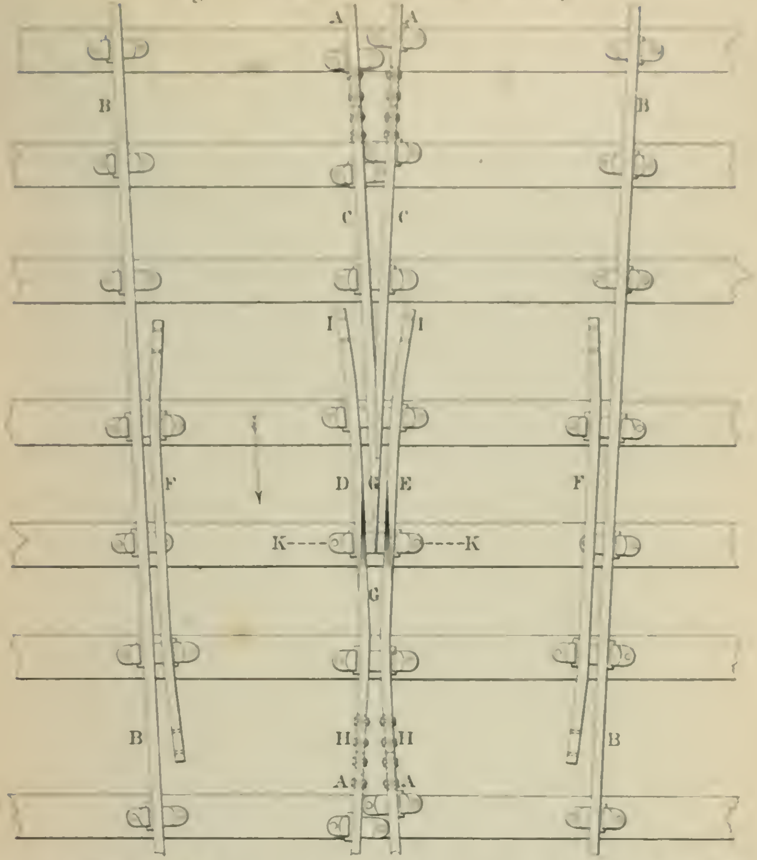


Scale 1/16th Ins. 12 9 6 3 0 1 2 Feet

(Proceedings Inst. M.E. 1856 Page 24.)

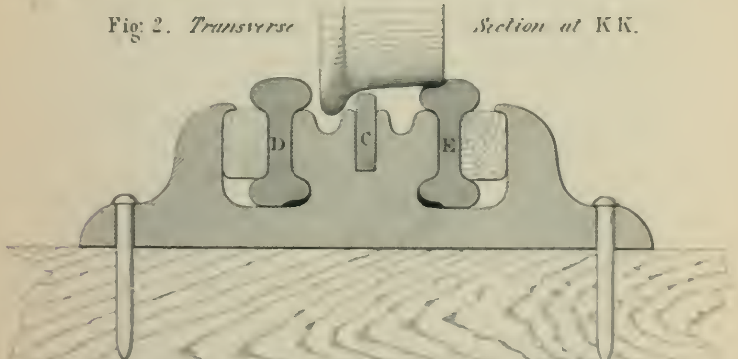
RAILWAY CROSSING

Fig 1. *Plan of Improved Crossing*



Scale 1/48th Ins 12 6 0 1 2 3 4 5 6 7 8 9 10 Feet

Fig: 2. *Transverse Section at* K K.



Scale 1/8th 0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches*

(Proceedings Inst. M. E. 1856. Page 35)

SAFETY VALVE.

Fig. 1. *Vertical Section*

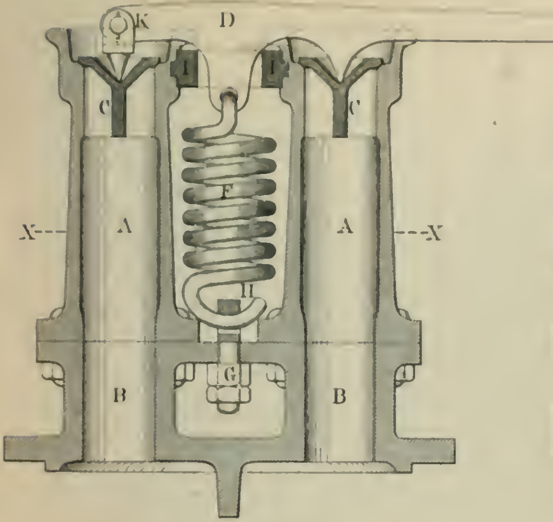


Fig 3. *Section at XX*

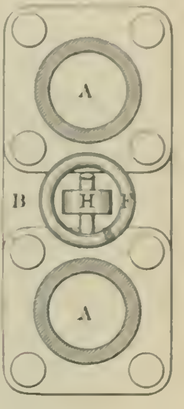


Fig. 2. *Plan.*

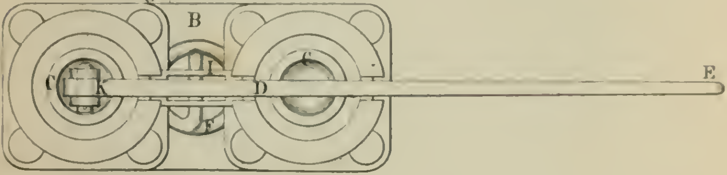


Fig. 4. *Vertical Section.*

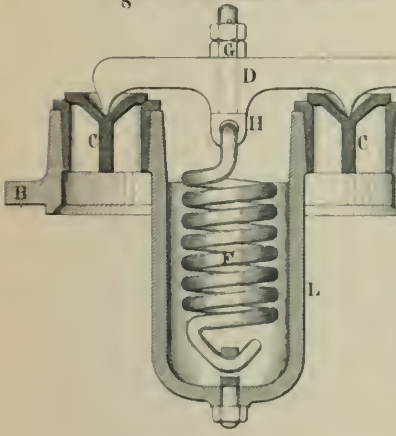
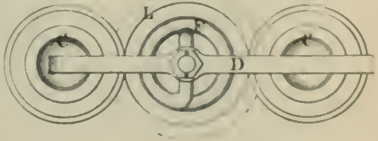


Fig. 5. *Plan.*



Scale 1/8th 0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches.*

(Proceedings Inst. M. E. 1856. Page 37)

SAFETY VALVE.

Plate 49

Fig. 6. *Vertical Section.*

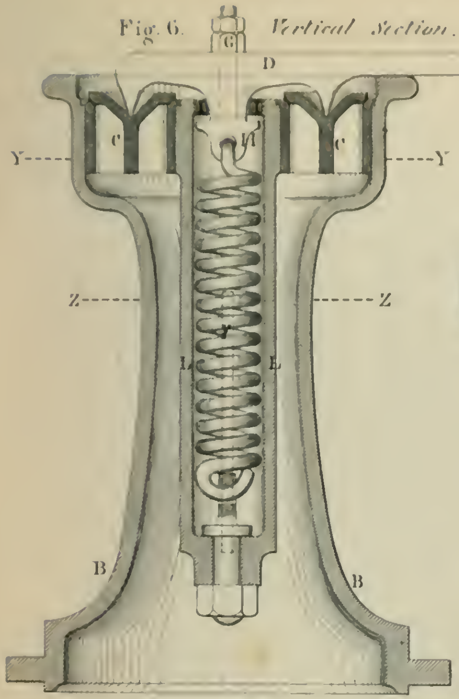


Fig. 8.
Section at YY.

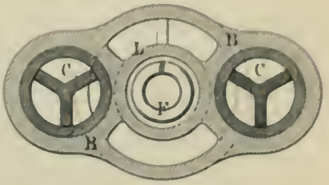


Fig. 9.
Section at ZZ.

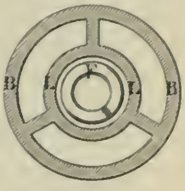


Fig. 7. *Plan.*

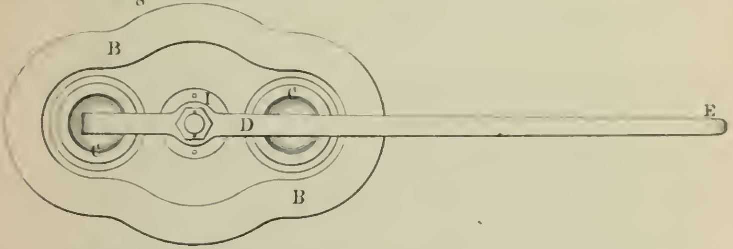


Fig. 10. *Vertical Section.*

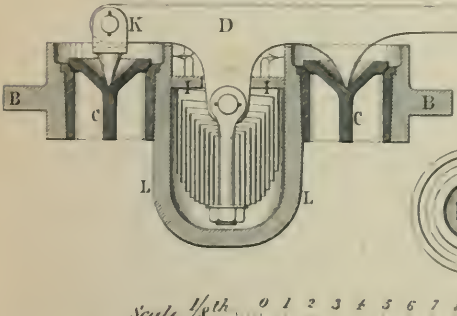
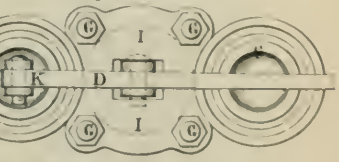


Fig. 11. *Plan.*



Scale 1/8th. 0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches.*

(Proceedings Inst. M.E. 1856. Page 37.)

PROCEEDINGS.

JANUARY 30, 1856.

The NINTH ANNUAL GENERAL MEETING of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 30th January, 1856; WILLIAM FAIRBAIRN, Esq., F.R.S., President, in the Chair.

The Minutes of the last General Meeting were read by the Secretary, and were confirmed.

The Secretary then read the following

ANNUAL REPORT OF THE COUNCIL.

1856.

The Council have the pleasure of reporting to the Members, on the occasion of the Ninth Anniversary of the Institution, the continued success and progress of the Institution.

The Financial statement of the affairs of the Institution for the year ending 31st December, 1855, shows a balance in the Treasurer's hands of £235 10s. 7d., after the payment of all accounts due to that date. The Finance Committee have examined and checked all the receipts and payments of the Institution for the last year, 1855, and report that the following Balance Sheet rendered by the Treasurer is correct.

(See Balance Sheet appended.)

The number of Members of all classes for the last year is 218, of whom 14 are Honorary Members, and 2 are Graduates.

The Council have to report the decease of two Members of the Institution during the past year, namely:—

ROBERT CROSLAND, ...	Bradford.
JOHN LINN, JUN.	Liverpool.

The Council have the pleasure of acknowledging the following Donations to the Library of the Institution during the past year:—

The Lowell Hydraulic Experiments, by Mr. James B. Francis, of Lowell, U.S., from the Author.

D. K. Clark on Railway Machinery, from the Author.

Useful Information for Engineers, by Mr. William Fairbairn, from the Author.

A Treatise on the Cornish Pumping Engine, by Mr. William Pole, from the Author.

Translation of Alban on the High Pressure Engine, by Mr. William Pole, from the Author.

On the Friction of Engines,	do.	do.
On the Strength and Deflection of Beams,	do.	do.
On the Pressure and Density of Steam,	do.	do.
On the Action of the Crank,	do.	do.
On the Motion of Fluids,	do.	do.
On the Prismatic Clinometer,	do.	do.
On the Errors of Time Keepers,	do.	do.
On the Water Supply of London,	do.	do.

Engravings and Description of the Compressed Air Piles employed in the construction of Rochester Bridge, by Mr. John Henderson.

Copies of Pamphlets on Public Baths and Washhouses, and on Town Buildings, by Mr. Henry Maudslay.

Engraving of the Wrought Iron Pier for the Royal Albert Bridge at Plymouth, by Mr. Joseph Radford.

Drawing of the Pumping Engines of the Wolverhampton Water Works, by Mr. Henry Marten.

Transactions of the North of England Institution of Mining Engineers.

Transactions of the Royal Scottish Society of Arts.

Transactions of the Liverpool Polytechnic Society.

Abstract Minutes of Proceedings of the Institution of Civil Engineers.

Journal of the Society of Arts.

The Artizan Journal, from the Editor.

The Civil Engineer and Architect's Journal, from the Editor.

The London Journal of Arts, from the Editor.

The Mechanics' Magazine, from the Editor.

The Mining Journal, from the Editor.

The Practical Mechanic's Journal, from the Editor.

The Railway Record, from the Editor.

Two miniature Busts in Cast Iron of George Stephenson and James Watt, by Mr. John Fernie.

Specimen of an improved Pressure Gauge, by Mr. F. Gray.

Specimen of an improved Tuyere, by Mr. C. Beyer.

Specimen of an improved Lubricator for Cylinders, by Mr. R. Eaton.

Specimens of Boiler Plate, Wheel Tyres, and Bar Iron, from the Farnley Iron Company.

Specimens of Compound Metallic Rods and Bars, by Mr. E. J. Payne.

Specimen of an improved Railway Spring and Axle Box, by Mr. W. B. Adams.

Specimen of an improved Axle Box, by Mr. G. M. Miller.

Specimen of an improved Axle Box, by Mr. W. G. Craig.

The Council have much satisfaction in referring to the practical value and interest of the papers that have been brought before the Institution during the past year, and expressing their thanks to the Authors of the papers for the valuable information they have furnished the Institution. The Council wish to urge on the attention of the Members the importance of their aid in promoting the objects of the Institution, by contributing papers on Engineering subjects that have come under their observation, and communicating the particulars of executed works, with the results of their working, that may be serviceable and interesting to the Members. The Council invite communications from the Members and their friends, upon the subjects in the list appended, and other subjects advantageous to the Institution; and also contributions to the Library, and to the collection of Mechanical Models and Drawings.

The following Papers have been read at the Meetings during the last year :—

Description of an improved Steam Hammer; by Mr. Robert Morrison, of Newcastle-on-Tyne.

On a new manufacture of Compound Metallic Rods and Bars; by Mr. Edward J. Payne, of Birmingham.

Description of an improved Safety Valve, for Locomotive, Marine, and Stationary Steam Boilers; by Mr. James Fenton, of Leeds.

Description of an improved Tuyere for Smiths' Hearths; by Mr. John Ross, of Birmingham.

Description of a new Moulding Machine for Cog and other Wheels; by Mr. Peter Rothwell Jackson, of Manchester.

On an improved Tuyere for Smiths' Hearths; by Mr. John Fernie, of Derby.

On the Commercial Economy of Working Steam Expansively in Marine Engines, with description of a new Double Expansive Marine Engine; by Mr. Edward E. Allen, of London.

Description of an improved Tuyere and Smiths' Hearth; by Mr. Charles Beyer, of Manchester.

On an improved Pressure Gauge, for Steam and Water; by Mr. John E. Clift, of Birmingham.

On an Equatorial Motion for Telescopes; by Mr. Thomas Richards, of Birmingham.

Description of a new Expansive Valve Motion for Steam Engines; by Mr. George M. Miller, of Dublin.

Description of an improved Blowing Engine; by Mr. Edward A. Cowper, of London.

On an improved Spring for Railway Carriages; by Mr. W. Bridges Adams, of London.

Description of a new Packing for Steam Engine Pistons; by Mr. David Joy, of Worcester.

On a new construction of Pumping Engine; by Mr. William Fairbairn, of Manchester.

On an improved Axle Box and Spring Fittings; by Mr. William G. Craig, of Manchester.

Description of a new construction of Steam Boiler; by Mr. Thomas Dunn, of Manchester.

Description of an improved Horizontal Condensing Steam Engine; by Mr. William B. Johnson, of Manchester.

On the construction of Packing Rings for Pistons; by Mr. John Ramsbottom, of Manchester.

The President, Vice-Presidents, and Officers of the Institution, and five of the Members of the Council in rotation, will go out of office this day, according to the Rules of the Institution; and the ballot will be taken at the present Annual Meeting for the election of the Officers and Council for the ensuing year.

The CHAIRMAN observed that the report of the Council that had been presented was very satisfactory, and the position of the Institution was decidedly encouraging. It gave him great pleasure to observe the progress made during the two years he had had the honour of filling the office of President. The numerous papers that had been brought before the meetings were valuable and interesting, and made an important addition, together with the drawings and models that had been presented, to the stock of the Institution. He had taken the opportunity, when commencing office, of calling the attention of the Members to the advantages that would arise from the formation of a library of reference in the Institution, and he was very glad to notice the advance that had been made towards that important object. He hoped all the Members would aid in extending the collection thus commenced, as far as they were able, by presenting to the Institution library any volumes of engineering and scientific books that they could spare; all such donations would be very serviceable, and also models and drawings, or such other contributions as were calculated to form a mechanical museum of reference, which he hoped would be carried out.

He had no doubt there would be a great increase in the number of members and the papers that were brought before the meetings, and that the Institution would go on widely extending its sphere of usefulness. Such an Institution was particularly valuable and important in a country such as their own, which was so dependent on mechanical engineering in all branches of manufactures and commerce, and also in war; and there was a wide field open for the exertions of its members. The opportunity afforded by the Institution for bringing forward and discussing subjects of professional interest, and comparing the results of the experience of the Members, would prove advantageous to all, and would confer important benefits in promoting improvements and ascertaining practical results.

The Chairman then moved that the Report of the Council be received and adopted, which was passed.

The Chairman said he had much pleasure in proposing a special vote of thanks to the authors of the papers that had been brought before the Institution during the past year, and to all the gentlemen who had presented books to the Library and drawings or models.

The vote of thanks was passed.

The Chairman announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following Officers and Members of Council were duly elected for the ensuing year:—

PRESIDENT.

Joseph Whitworth,	Manchester.

VICE-PRESIDENTS.

William Fairbairn,	Manchester.
Benjamin Fothergill,	Manchester.
John Henderson,	Birmingham.
James E. McConnell,	Wolverton.
John Penn,	London.
John Scott Russell,	London.

COUNCIL.

Charles Beyer,	Manchester.
John E. Clift,	Birmingham.
Alexander B. Cochrane,	Dudley.
Sir Charles Fox,	London.
John Ramsbottom,	Manchester.

TREASURER.

Henry Edmunds,	Birmingham.

SECRETARY.

William P. Marshall,	Birmingham.

The following New Members were also elected:—

MEMBERS.

John Brown,	Darlington.
William Elliott Carrett,	Leeds.
Charles Fay,	Manchester.
Thomas Hawksley,	London.
John Hopkinson,	Manchester.
Robert B. Longridge,	Manchester.
George H. M. Muntz,	Wednesbury.
George Piggott,	Birmingham.
Robert Russel,	Manchester.
Charles P. B. Shelley,	Birmingham.
George Tosh,	Maryport.
Thomas Truss,	Chester.
Charles W. Wardle,	Leeds.

GRADUATE.

William Waller,	Lincoln.

The following Paper, by Mr. Henry Marten, of Wolverhampton, was then read:—

DESCRIPTION OF THE PUMPING ENGINES OF THE WOLVERHAMPTON WATER WORKS, WITH SOME REMARKS ON WATER PUMPING.

The engines described in the present paper, and of which drawings have been presented to the Institution, have been erected and at work now some years. They consist of a pair of engines at Tettenhall, constructed from the designs of Mr. Thomas Wicksteed, M.I.C.E., and erected in 1847 by Mr. James Kay, of Bury; and also an engine at Goldthorn Hill, constructed in 1851 by Messrs. Hawthorn, of Newcastle-on-Tyne, members of this Institution.

The engines at Tettenhall are single direct-action non-condensing engines, and are shown in the general view, Fig. 1, Plate 41, to a small scale, and in detail to a larger scale, in Figs. 2 to 8, Plates 42, 43, and 44. The cylinders A A are 36 inches diameter, and 9 feet 6 inches stroke. The plunger pumps B B, Fig. 5, are 13 inches diameter, lifting about 300 feet. The steam is admitted to the cylinder at a pressure of about 35 lbs., and cut off at 2-3rds of the stroke. The boilers are cylindrical, two in number, 26 feet long, and 6 feet diameter, with two tubes in each, 25½ inches diameter, and internal fires. The flame from each fireplace passes along the tube, thence round to the front again by the side of the boiler next to its tube, and thence the two uniting pass along the bottom into the chimney.

The boilers were originally constructed with only one flue in each, of 3 feet 9 inches diameter; but it was found that the steam space was much too small for the size of the cylinders, and that the great draught of steam from the boiler at each stroke of the engine, and the consequent irregularity of pressure, so deranged the tube as to cause a constant leakage at the angle irons at each end. It has been found in practice that the two smaller tubes are in every respect preferable to the single one, as they allow more steam room, better heating surface, and afford convenience for cleaning all round under the bottom, and by permitting the water level to be nearer the centre of the boiler shell, they admit of a larger water surface for the delivery of the steam as it is generated in the water, so that the ebullition is less violent, and the formation of steam more rapid.

The boilers are covered with loam or moulding sand to a depth of about 6 inches over the top. This substance, which should be protected by a roof from being blown away, is found to be a very good non-conductor, very little heat radiating through it to the upper surface. It has also this advantage over nearly all other materials employed for the same purpose—that no condensation can take place in it within two or three inches of the boiler plates, since for that distance it forms a sand bath as hot as the steam, which, in the event of any leakage, blows through it dry, and consequently no corrosive action upon the plates can take place. Condensation cannot occur until at a distance of three or four inches from the plates, spreading thence very gradually with the escape of the vapour towards the surface of the sand, where a moist patch is observed, indicative of what is going on below. With a material of this description, any portion of the boiler top can be uncovered with a shovel and examined at once. For the purpose of experiment at Tettenhall steam blows at two places in the boilers covered in this manner were suffered to remain unrepaired for a couple of years, in order to try the effect fully, and the result was an entire absence of corrosive action, as described above. In the opinion of the writer, loam sand is much preferable for this purpose to any other material, provided always that it is protected by a roof or covering. It is much cheaper than felt, brick, or iron casing, and the plates are much more readily inspected than with the latter coverings. It is also much superior to furnace ashes, cinders, or riddlings, which are often placed over boilers, as these substances frequently contain acids and other chemical impurities, which on being brought into contact with waste steam, act very injuriously on wrought iron; in some situations the author has seen plates nearly eaten through from improper coverings of this description.

In the pump work, shown in Figs. 5, 6, and 7, there is little requiring special notice: the valves are ring valves, rising on a centre spindle, as shown in Fig. 8; they are of cast iron galvanized, beating on wooden faces. Originally they beat upon a mixture of lead and tin, but this soon became loose in the seating and leaked; oak was then tried, but the acid peculiar to this wood corroded the cast iron, so that these beats were obliged to be discontinued. Lancewood, box, and beech have also been tried, but nothing answers so well as holly, which is now employed, and continues to work well.

The area of the suction valve C is 325 square inches, being about 2½ times the area of the plunger, and that of the delivery valve D is 163 square inches, or about 1⅓ times the area of the plunger. The enlargement of the suction valve to this extent is found to be very serviceable where the velocity of the plunger is likely to be great in the ascending stroke.

The steam valve E, the equilibrium valve F, and the exhaust valve G, are of gun metal, and on the double-beat construction. Their areas are as follows:—

Steam Valve . .	50	square inches	=1-20th of area of cylinder.
Equilibrium Valve	50	„	=1-20th of area of cylinder.
Exhaust Valve .	78	„	=1-13th of area of cylinder.

The piston rod and pump rod are connected with a cross head H, working on V slides attached to the supporting columns I, Figs. 2 and 3. The plug rod K and the valve motion are worked from a slight wrought iron beam L under the cylinder floor, connected at one end to the cross head H, and at the other end slung to parallel links. The feed pump M is also attached to this beam. The water for the feed is passed through a heater N, situated in the corner of the engine house, and formed by an enlargement of the waste steam pipe, 1 foot 6 inches diameter, along the centre of which for some distance the feed pipe is conducted, occupying about two thirds the area of the heater.

The engine is regulated by a water cataract governed by a small ratchet wheel and screw. The number of strokes per minute varies from 3 or 4 to 10 or 11, the average speed of the piston being 130 to 140 feet per minute; the quantity of water delivered per stroke is 56 gallons. The area of the plunger is 132 square inches, and the pressure on the bottom of the plunger is 130 lbs. per square inch, making a total dead load of 17,160 lbs., equal to a dead pressure of 16¾ lbs. per square inch on the surface of the steam piston.

These engines are working for their kind at a fair duty, performing about 27,000,000 lbs. lifted one foot high per minute, with a consumption of 1 cwt. of the small common slack of the neighbourhood. With Newcastle or Welsh small coal they would perform a duty of 36,000,000 lbs.

The engine at Goldthorn Hill, shown in the general view to a small scale, Fig. 9, Plate 41, is given merely as a sample of a good useful pumping engine fitted for this neighbourhood. It is a low-pressure condensing beam engine ; the cylinder is 48 inches diameter, with an 8 feet stroke ; the boilers are 30 feet long, and 7 feet diameter, with two tubes, 2 feet diameter beyond the furnace, and 2 feet by 2 feet 4 inches at the fireplaces. The pressure of the steam is about 15 lbs. per square inch. The boilers are clothed with felt and wood lagging, which was completed before the experiments with loam sand had been tried.

To avoid the almost constant trouble which arises from leakage at the steam valves on the boiler tops from the expansion and contraction of the main range of steam pipes, Mr. Hawthorn suggested that the main steam pipe should be conducted to the steam chest with a quadrant curve, as shown in the plan, Fig. 9, so as to allow the two extremities connected with the steam nozzles a considerable amount of expansion and contraction, without a thrust sufficient to break any joints ; and the writer has pleasure in stating that this arrangement has been completely successful, as there has not been the slightest leak either at the nozzles or steam chest. This arrangement is useful and efficient where there is one steam pipe leading off from between two boilers ; where however the steam pipe leads off from one side, or where there is a range of more than two boilers, it is not applicable ; and in these latter cases the writer has found no expansion joint so simple and effective as the wrought iron diaphragm joint, consisting of a couple of circular wrought iron plates, about 2½ times the diameter of the pipe, bellied about 3 inches, and rivetted together at the outer rim and to flanges on the main range of steam pipe.

There is another point of detail in connection with the boilers to which the writer would wish to call attention, as it is useful though frequently overlooked. The hot and cold feed and blow off are all led into and out of the boiler through the same pipe ; this arrangement avoids the numerous holes usually cut into boilers for these purposes, and any impurity which may enter the boiler with the hot and cold feed is deposited in close proximity to the blow off. In the present instance, the pipe is of wrought iron, and is rivetted on to the underside of the front end of the boiler, and the arrangement of the valves is somewhat similar to those of a bath, where the hot, cold, and outlet valves all take off the same pipe.

It is also important that the feed should enter the coldest portion of a boiler, which from the action of the currents in those with internal flues is just under the fire grate. When attention is not bestowed on this point, it frequently happens that seams and rivets leak from the sudden changes of temperature to which they are liable.

The boilers are flat ended, and have no stays, but there are three stout T irons rivetted on to the flat plates forming the ends, so as to stiffen them against the pressure. This remark applies also to the boilers at Tettenhall, which are flat ended, with T irons of the same description, working under a pressure of 35 lbs. per square inch.

The writer's experience has led him to the conclusion, that, as a general rule and as far as circumstances will possibly permit, all boilers should be so constructed as to require no artificial support from stays ; these tend to pull a boiler out of shape, loosen rivets, and are difficult effectually to fasten or repair ; flaws are not readily detected in them, and often when their services are most required they give way from hidden corrosion, or else they strain the boiler so as seriously to damage it, if not fixed exactly in the direction of the line of tension.

The pumps at Goldthorn Hill draw the water from a well about 90 yards deep, and this depth is divided into two lifts of about 45 yards each ; the diameter of the bottom working barrel is 14 inches, and that of the top 13½ inches. The valves are ring valves of gun metal, with gun metal seats. The average speed of the piston is 100 feet per minute, and the quantity of water raised per stroke is 48 gallons ; the total dead pressure is 19,305 lbs., equal to 130 lbs. per square inch of area of the working barrel, and to 10½ lbs. per square inch of surface of the piston. The steam is cut off at about half stroke; the steam, equilibrium, and exhaust valves are double-beat gun metal valves, and their sizes are as follows:—

Steam Valve . .	51	square inches	=1-36th of area of cylinder.
Equilibrium Valve	51	,,	=1-36th of area of cylinder.
Exhaust Valve .	64	,,	=1-28th of area of cylinder.

The duty of the engine averages about 40,000,000 lbs. raised one foot high per minute, with 1 cwt. of slack.

The Tettenhall engines deliver the water over a stand pipe, 180 feet high, whence it flows by its own gravitation to the town. The Goldthorn Hill engine delivers through an air vessel into two covered reservoirs lying near the engine, and raised about 20 feet above the top lift, and holding together 1,500,000 gallons. The reservoirs are arched over, and covered with two feet of soil, for the purpose of preventing vegetation and variation in the temperature of the water when exposed to the atmosphere, and this end is answered well, the water remaining for months of the same temperature, and perfectly clear and free from all vegetable or animal impurities. The reservoirs are prevented from being overfilled by a self-acting check valve, shown in Figs. 10 to 13, Plate 45, which shuts against any supply beyond a certain limit, so that the man working any pumping engine at a distance at once knows when his work is done. The valve is so arranged, that immediately the engine ceases to work, the supply to the town is maintained from the reservoir through the flap valves O, underneath the self-acting stop valve P, which open immediately there is any requirement for the supply to the town.

The object of a stand pipe is that the water may be always delivered from the engine over one uniform height, and consequently of one uniform pressure on the engine, whatever varying circumstances may affect the delivery after the water has once passed the top of the stand pipe. Thus far it is useful, as the engine can always work under a defined pressure; but it is rather a costly and unsightly mode of attaining what in practice is found to be an unnecessary degree of perfection; since with a tithe of the cost all the necessary safety can be procured by pumping into an air vessel with a check valve on the delivery side; so that in case of a pipe bursting, or any sudden diminution of pressure taking place, it would be impossible for the engine to "go out of doors" at more than a certain regulated speed, by the partial contraction of the area of discharge through the self-acting movement of the check valve. Unless the stand pipes are carefully cased in winter, they are in great danger of being frozen, and very serious consequences have arisen from this cause. There is also a drawback with them, on account of the great weight of the column of water which has to be set in motion from a dead stand at each stroke of the engine.

The successful working of any pumping engine is dependent in a great degree upon the perfection of the pump valves. These must be so arranged as to deliver the water with ease and rapidity, and without any concussion in closing. As an illustration of the great practical importance of this question, it may be mentioned that when the Cornish pumping engine was first introduced for Water Works purposes on a large scale, it was on the point of being altogether abandoned on account of the imperfection of the pump valves. The valves were of very large area, and on the old butterfly principle, and consequently, under the heavy pressure at which they were working, the concussion caused in shutting was so violent as to occasion serious alarm for the safety of the machinery and foundations. For some time the problem to be solved—to find a method of constructing a valve which should present a maximum area of discharge, with a minimum area of surface exposed to the concussion of the recoiling load at the termination of each stroke of the pump—presented difficulties that appeared insurmountable, until the idea of the application of a modification of the double-beat steam valve for the purpose happily occurred to Messrs. Harvey and West. These gentlemen adopted the expedient of making the double-beat valve self-acting, by slightly contracting the upper beat, as shown in Fig. 14, so as to allow the difference between the areas of the outside of the upper beat and the inside of the lower, as a surface upon which the pressure might act for opening and shutting the valve. This plan answered admirably; the valve in opening a very slight distance gave a large area of discharge, and the area upon which the recoiling column descended, being only the difference between the upper and lower areas, and not the entire area of discharge as in the old butterfly valve, formed a surface insufficient to cause any concussion. This valve also afforded under all circumstances a means of regulating the pressure tending to shut the valve, whatever might be the height of the column of water or the total pressure of the recoiling column, by adjusting the difference of area of the upper and lower beats inversely in proportion to the height of the column.

For ordinary purposes, that is to say for small lift pumps and colliery engines, the butterfly valve is very serviceable, as there are no expensive faces to be ground up, or liable to derangement from impurities or grit in the water, and they are easily and readily repaired on the spot. For a class of work one grade higher than ordinary, the writer has found no description of valve answers better than the double-beat ring valve, similar to those employed in the engines at Tettenhall and Goldthorn Hill, and shown in Fig. 8. Large valves of this construction, of 16 to 20 inches diameter, answer well made of cast iron with wooden beats. Smaller valves, of 8 to 15 inches diameter, are better of gun metal working face to face. Of the latter description the writer has had some at work for more than two years, under a pressure of 260 feet head, without any perceptible wear having occurred.

At the Hull Water Works, a new description of valve has been adopted in one of the pumps for some time, and is found to answer remarkably well. The valve is shown in Figs. 15 and 16, and consists of a pyramid of circular seats, one above another, in each of which there are a number of small circular beats, about 2 inches diameter, into which a corresponding number of gutta-percha balls drop. The action of this valve, as will be seen from the figure, is very simple. It was invented by Mr. Hosking, and inserted in the place of a double-beat valve. It is 22 inches diameter, and works under a head of 160 feet, in connection with a plunger pump with a direct-action steam cylinder. Immediately upon starting it was found that this valve lightened the burden of the engine about 1½ cwt., and it has since been working with great satisfaction for a considerable period.

The advantages of this valve are more than are apparent at the first glance. In the first place, it is much safer than any other form of valve, as will be seen at once, supposing a piece of wood or other material should pass through the pump, as is not unfrequently the case. With the ordinary valve, if it should be caught on the beat, it would hold the whole valve open, and let the engine "come out" with a run, and possibly cause considerable damage; but with the small balls, a piece of wood so caught could prop open only 1 out of 56 balls, which is so small a per-centage of the whole opening, that it would merely enable the man in charge of the engine to perceive that there was a little amiss by an increase of leakage, but could cause no damage.

In the second place, the balls being nearly of the same specific gravity as the water are just floated open, the moment the current turns in their favour; whereas in all other valves, in addition to the column of water to be lifted, there is also the weight of the heavy metal valve to be opened and held suspended during each stroke. This was practically exemplified in the Hull case mentioned above, where a considerable load was at once removed from the engine on the application of the new valve. With larger valves this point becomes one of still greater importance, as they often weigh 5 or 6 cwt. each.*

In the next place, whilst the area of discharge may be made fully equal to that of the plunger, the area exposed to concussive action in the closing of the valve is reduced to the smallest possible limits, being practically reduced to the impinging force upon one ball, the last one that shuts, that is, 1-56th only of the total area of beating face This is owing to the circumstance that the balls do not all rise to the same height above their seats; and consequently, as the force of the current acts upon each individually, on the cessation of motion they shut in accordance with the height they have to fall, and a communication exists between the water on the upper and under side of the valve, until the absolute closing of the last ball. The result is, that although the difference in time between the falling of the various balls must be exceedingly minute, it is such as practically to prevent all concussion.

Lastly, the valves constructed on this plan are very readily repaired. It is only necessary to keep a few spare balls ready to be inserted in the place of any that may be occasionally damaged; and the old ones, on being warmed and recast in a mould kept for that purpose, are again as good as new.

Where it is proposed to work with a high pressure of steam, cut off so as to allow of a considerable expansion, the writer's experience has led him to prefer the beam to the direct-action engine. He has observed that as a rule direct-action engines working under a high initial pressure are apt to start off at a speed which jars and strains the whole of the machinery throughout. The speed attained by the piston as driven indoors at the beginning of the stroke is many times greater than the average velocity per minute, and consequently, unless all the parts are made extra strong in proportion, the bearings wear out with great rapidity, and the machinery is soon loose at every joint. In a beam engine, on the other hand, a very large proportion of the initial force is absorbed in overcoming the inertia of the heavy beam, which thus becomes a reservoir of surplus force in the earlier portion of the stroke to be given out during the later, and the result is that a comparatively steady velocity is maintained throughout the stroke, much to the advantage of the whole of the machinery; indeed it is only with this adjunct that expansion can be carried safely to a very high degree. The beam in fact is a reciprocating fly wheel, and is attended with precisely the same action and the same beneficial results. The writer is acquainted with a case of two large expansive engines of nearly the same size, working near together, of which one has an open net-work beam of about 30 tons, and the other a heavy strong beam of 45 tons weight. The difference in the working of the two engines is very perceptible, and nearly 5,000,000 lbs. duty in favour of the heavy beam, in the steadiness and smoothness of the motion. In many cases where a jar is perceived in pumping engines working with a high expansion, it may be cured by increasing the weight or inertia of the beam.

For pumping a large quantity of water through an unusually great length of main pipe under a heavy pressure, the writer's experience has led him to prefer a description of engine consisting of a pair of high pressure expansive double-acting beam engines, coupled together at right angles to one large fly wheel. The pumps should be of the combined plunger and bucket description, with Hosking's valves. There should be an air vessel and back flap valve to each pump, with a blow-off valve loaded to a certain weight, so that in the case of any recoil in so great a length of main, the pumps would not be burst. Along the main pipe, at each 50 feet of elevation above the pumps, the insertion of a back flap valve is required, so that in case of any pipe bursting the whole main should not be run dry. The leading point to be kept always in view in the design and construction of engines under these circumstances is the maintenance of a constantly uniform flow of water through the main pipe from the pumps. This is provided for by the compound double-acting pumps and the large air vessel accommodation, together with the coupling of the engines at right angles. The boilers should be similar to those of the Goldthorn Hill engine.

Many engineers prefer a double cylinder engine for conducting expansive operations: but although in some circumstances this may be advantageous, as for driving machinery where uniformity of power throughout the stroke is a desideratum, yet for large pumping engines the writer prefers single cylinder double-action engines. The arrangements with a double cylinder are much more complicated, and he finds that all useful degrees of expansion can be carried out sufficiently with a single cylinder.

A very cheap and effective description of temporary pumping engine for rough colliery purposes, where saving in first cost is a more important object than great economy of fuel, came some time since under the writer's observation at a colliery near Nailsea. The engine was constructed by Mr. Hughes, of the Uskside Foundry, Newport, and consists simply of a large open topped cylinder placed vertically on two cross beams over the pit shaft. The working apparatus consists merely of a steam valve for admitting the steam under the piston, and an eduction valve for letting it out, with a steam slide throttle valve, and eduction slide throttle valve, for regulating the rate for the admission and exit of the steam. The two former valves are worked by tappets attached direct to the piston rod: the two latter are adjusted by hand, so as to regulate the number of strokes per minute, the engine being in fact its own cataract. This engine is remarkable for its simplicity and cheapness of construction, and has now been at work for some years. The consumption of fuel with a good description of boiler is not more than the average of ordinary colliery pumping engines as at present constructed. The general arrangement for a plunger pump would be as described above; with a lift pump it would be necessary to have a balance bob. Its security is also very considerable, since if the two throttle valves are properly adjusted, no great damage could occur should one of the other valves stick, as the piston could not travel either up or down faster than the steam could pass through the guarding throttle valve. It is also a portable description of engine, which is sometimes a recommendation in proving mines.

For raising water from mines in a district such as this, where fuel is abundant, a reduction in first cost is a much more important question than in districts where the fuel has to be imported at great cost; that is, setting the first outlay and interest for erecting a large expansive engine with low consumption of fuel against the smaller outlay with larger expenditure of fuel, it will generally be found that, in districts such as this, the latter is the better within certain limits for the party investing capital in opening mines. Everybody concerned in opening works of this description must be aware how important it is to economize first outlay, whereas when returns commence a small extra annual cost is not felt. Under these circumstances, in a district such as this, the writer would not recommend the erection of expensive Cornish engines for drainage purposes. Their first cost in every respect is very great; a cylinder and all machinery to match to do 1000 horse power work is put down to perform really only 200 or 250 horse power, and all the parts of the ponderous machine have to be constructed of sufficient strength to resist the heaviest initial blow of the steam.

The plan of plunger lifts, carried out so extensively under this system, is not only expensive, but highly inconvenient in narrow pits. Whereas much the better and cheaper plan is a simple lift pump, with the beam balanced, so that the weight of the pump rods shall just carry the engine "out of doors." Plungers are in their place for forcing water above the level of the engine, as in the case of Water Works, but in the engine pit of a mine, with a strong and heavy rod having numerous guides and rollers, they are very inconvenient, and if the engine is properly balanced they effect no saving, as the piston must not travel faster than the rate at which it is safe to work the bottom set of rods, which must necessarily be attached to a lift pump.

In concluding these few observations on pumping engines, especially in reference to this district, the writer cannot but observe with regret, that although pumping machinery is now carried to such perfection, there has been for so many years such a large amount of the mineral wealth of South Staffordshire lying inaccessible, from the want of some comprehensive and efficient system of co-operation for draining the mines. In former times, before the invention of the steam engine, when the mechanical difficulties appeared insuperable for winning the deep mines, there was evidently a considerable amount of co-operation in the endeavours of the "old men" to relieve the water from the upper levels by means of adits and tunnels. At the present day, when mechanical difficulties have been so completely overcome, and the means for obtaining unlimited pumping power are at hand, these co-operative relationships, with some few exceptions, appear altogether abandoned. It ought not to be more inpracticable for some of the most experienced mine agents to parcel out the South Staffordshire coal district into satisfactory drainage areas, than it is for the Fen Bailiffs of Lincolnshire to arrange their respective districts, and satisfactorily apportion the charges to be made on the various estates. Although a good deal of floating attention has been paid to this subject at various times, yet hitherto no thoroughly digested and comprehensive plan has been devised. There is no doubt however that the urgency of the case is daily becoming greater, and it will afford the writer great satisfaction should these few observations in any way conduce to some practical effort being made towards the accomplishment of so important an object.

The Chairman said that the subject of the paper was one of great importance, and much valuable information had been given by the author; the numerous suggestions thrown out were useful, if only in directing attention to the topics to which they referred, and opened a wide field for investigation and discussion. The proposal of a plan for the systematic drainage of the mines of that district demanded serious consideration, with a view to maturing the scheme, and reducing it to a form capable of being practically carried out. Any information in reference to such an undertaking would be valuable, because the drainage of the large coal districts was becoming now of such importance as to require the most careful attention and the application of sound principles on the part of the engineer. Amongst the several points noticed in the paper, the new form of pump valve described struck him as having considerable value; he enquired what was the size of the small balls composing the valve, and how they were prevented from coming out of their proper seats.

Mr. Marten replied that the balls were 2½ or 3 inches diameter, the apertures in the seat being 1 inch less; each ball was prevented from coming out of its place by a cap projecting from the seat immediately above, and by this simple arrangement, by slackening the top nut, all the rings and caps became liberated, and any of the balls could be taken out and replaced with great readiness.

The Chairman observed that the number of separate balls would prevent any considerable portion of the valve from sticking fast in consequence of small pieces of dirt getting into the valve; but it would be important to protect the valve with a fender in order to prevent it from being choked by the entrance of any body too large to pass through the small openings.

Mr. MARTEN said that the only situation where he had known the valve used at present was for Water Works, where the water was clear and had been previously strained; in addition to the Hull Water Works, it had been adopted also at the Chelsea and the Deptford Water Works.

Mr. FENTON said that he had seen the original form of Hosking's valve in work, and it was really a very good and ingenious invention; Mr. Hosking, the inventor, was engaged in the construction of the High Level Bridge at Newcastle, and the original form of the valve with india rubber flaps instead of the balls had been used extensively in that neighbourhood, and was employed for common colliery purposes, with any sort of water, not clear water alone, and no difficulty was experienced from choking with dirty water; in this valve the india rubber flaps were arranged in a pyramid, in the same manner as the balls.

The CHAIRMAN remarked that the Tettenhall engines had been described as cutting off the steam at only 2-3rds of the stroke, which gave rather a low degree of expansion, and left considerable margin for further economy in fuel by expanding to a greater extent.

Mr. MARTEN said that it was certainly a low degree of expansion, but there was no condensation, and the engines were direct-acting; a higher degree of expansion had been tried at first, but the action of the engine was rendered too sudden, and the violent blow of the steam caused the motion to be so remarkably quick in starting the stroke, that it was not found safe, from want of inertia sufficient to absorb the excess of initial force; this could only be supplied by having a beam, balanced on its centre, and offering no resistance to motion except the inertia of its weight, which acted as a regulator to equalize the moving power of the engine.

The CHAIRMAN said that he fully concurred in the value of a heavy balance beam as a regulator, and the disadvantage of the irregular motion that was produced by cutting off early, where not counteracted by the inertia of a heavy mass to be put in motion; and the observations in the paper on the comparative effect of a light and heavy beam were very appropriate. In the case of the Tettenhall engines, he thought it would have been preferable to have a cylinder of larger size, and working with a higher degree of expansion, making the engine with a balance beam, if direct-acting, and employing the extra force of the steam to overcome the inertia of the load at the beginning of the stroke, relying upon the momentum afterwards to carry the engine to the end of the stroke.

Mr. MARTEN observed that the superiority of the heavy beam engine was well exemplified by the case of the two beam engines that had been mentioned; they were both Cornish engines, but the one with the light open beam had a jar in its motion, and the engine gave a perceptible start or jump on starting each stroke; whilst the heavy beam engine worked smoothly and without jar, and with 5,000,000 lbs. more duty. In the Goldthorn Hill engine there had at first been a little jar at starting, but this was entirely removed by adding a balance weight of 2 tons weight upon each end of the beam.

Mr. GARLAND enquired what had been the reason for the Tettenhall engines being made non-condensing.

Mr. MARTEN replied that these engines were the first erected, and the water having to be pumped out of sandstone rock, it was thought that there might not be much to spare for condensing; fuel also being cheap, the engines had been intended as a simple and economical arrangement for pumping.

The CHAIRMAN asked what duty had been taken as the standard for comparison in the paper, and what was the relative consumption of the Tettenhall engines.

Mr. MARTEN said that the ordinary standard of duty of Cornish engines had been employed, which was taken usually at about one million pounds raised one foot high per cwt. of coal for each inch in the diameter of the cylinder: and accordingly the Tettenhall engines, when considered as non-condensing, were working at a fair duty, having 36 inch cylinders, and giving 27,000,000 lbs. with the common slack of the neighbourhood, equivalent to 36,000,000 lbs. with Newcastle or Welsh small coal.

The CHAIRMAN enquired whether the plan of heating the feed water by means of the exhaust steam, that had been mentioned, was found to be productive of much practical advantage.

Mr. MARTEN replied that some saving of fuel was effected, but this might no doubt be rendered more important in amount by improved construction of the heating apparatus. After heating the feed water the waste steam had originally been thrown direct into the chimney, but in consequence of the stack having been considerably injured by the quantity of moisture in the foundations, caused by condensation of the steam in the chimney, it was now conducted into a well, where it was condensed, and a flue from the well to the chimney carried off the vapour rising from the water.

The CHAIRMAN remarked that the sand covering over the boilers appeared a simple and efficient protection, and likely to answer well; it was important to avoid any risk of corrosion of the boiler plates where concealed from inspection.

Mr. MARTEN said that the sand covering had been found most satisfactory; the Tettenhall boilers had been originally covered with felt, but this partly rotted off, and was all removed, and the sand was then tried and had been employed ever since. The sand acted as a dry sand bath, being invariably quite dry within 2 or 3 inches of the boiler, and so hot that no steam that escaped could be condensed within that distance from the plates, and thus no corrosive action could take place. Much damage was often done to boilers by covering them with ashes or brickwork; in case of any steam blows, the steam was condensed in contact with the plates, and the plates were eaten through by the acid ingredients of the ashes, which were called into action by the condensed steam; he had seen some bad cases of boilers covered with ashes and brickwork, where the plates had been corroded very thin in a short time. A practical illustration of the value of covering the boilers was afforded by a pair of blast engines at his own works, blowing four furnaces. These were now supplied by four boilers covered with sand, and were giving a blast of 4 lbs. per square inch pressure, with steam of 20 lbs. pressure; but previously, when covered with a roof only, a blast of only 3 lbs. per square inch pressure, with steam of 15 lbs. pressure, was obtained, although five boilers were used.

Mr. FENTON asked what sand was employed for covering the boilers, and whether any care was required in its application.

Mr. MARTEN answered that common moulding sand had been used, but the quality was immaterial, and any clean sand might be used. The sand was filled up level all over the boiler to a depth of a few inches above the highest part, and it had an important advantage over other modes of covering, in the facility which it afforded for examining any part of the boiler, as it was merely necessary to shovel away the sand from the part to be examined, which was as easily covered up again. In the case of the Tettenhall engines, steam blows had been left unrepaired for two years, in order to test the sand covering in a satisfactory matter; they had been frequently examined during that period, by shovelling away the sand in the manner described, and on arriving within a few inches of the boiler, the steam issuing through the sand was so dry, that it had not at all the appearance of steam, but rather of hot air blowing out; no signs of corrosive action on the plates had been detected in any case.

The CHAIRMAN remarked that the boilers had been mentioned as being constructed without any stays, and he quite agreed in the principle of depending on the form of the boiler for strength, and not upon artificial stays. The flues of the boiler at Goldthorn Hill had been described as of circular section, but elliptical at the fire places, a plan which he had generally adopted formerly, but he made them now truly circular throughout, having found that there was no practical superiority in the working of the elliptical flues, and there was undoubtedly no form so correct as the circle. It was very important to ascertain exactly the relative strength of these forms, and he had the pleasure of stating that a grant of £300 had been promised by the Royal Society for experiments, in which he was about to be engaged, to ascertain the strength of flues of various sections. He hoped the enquiry would be extended to an experimental investigation of the laws relating to the pressure and density of high pressure steam, as he felt convinced that the time was not far distant when the pressure employed for the ordinary working of steam engines would have to be increased to three or four times the present working pressure.

Mr. FENTON observed that the experiments contemplated would be of great practical value; it was well known that a flue sometimes collapsed under a pressure per square inch much lower than that required to burst it; but by diminishing the size of the flue, it might be made capable of resisting a very great external pressure, as in the case of the tubes of locomotives, and it was very important that extensive experiments should be made in connection with this subject, in order to ascertain the law of strength and the correct form in all cases; as there must certainly be a definite relation between the crushing strength of a tube of two inches diameter and a flue of two feet.

Mr. H. WRIGHT hoped the experiments would apply also to the strength of the flat ends of boilers, and the best means of supporting them.

The CHAIRMAN said that further information upon the strength of flues was much wanted in practice, as it was evidently of no use to have a flue which was in danger of collapsing under steam of 40 lbs. per square inch pressure; and yet accidents had occurred from collapsing, where that pressure was probably not exceeded. He was not aware that any experiments had been yet made to determine the law of resistance of the cylinder to external pressure, but as soon as these were made, formulæ for calculating the strength of flues under different circumstances would be readily deduced.

The paper that had been read gave much valuable information on the principles and working of pumping engines, and would without doubt be found practically useful by many of the members. He proposed a vote of thanks to Mr. Marten for his paper, which was passed.

The following Paper, by Mr. John Penn, of London, was then read:—

ON WOOD BEARINGS FOR SCREW PROPELLER SHAFTS.

In the bearings of the shafts of Screw Propellers a considerable difficulty has been experienced, when the screw has not been kept in regular work, but has been required to stand still for several hours or even days together, as is more particularly the case with war steamers. In such cases it has been found requisite, in timber vessels having copper sheathing, to protect the wrought iron screw shaft by a brass casing, wherever exposed to the action of the sea water; since otherwise the galvanic action excited by the copper causes a serious and rapid corrosion of the iron shaft, and its bearings soon become injured. A similar action takes place also in iron vessels, but not to the same extent. The shaft is consequently cased throughout with a brass tube A, as shown in the longitudinal section, Fig. 1, Plate 46, and the transverse section, Fig. 2; the tube A fits close to the shaft B at the journals, and is loose from it between them. But the friction and wear at the bearings is in this construction very great, as the brass casing of the journals has to turn in brass bushes; and the result is a very rapid wear, and a great difficulty in keeping the bearings long at work. Moreover the screw propeller itself is a heavy mass, weighing in some cases from 10 to 12 tons, coupled at the end of the shaft by a cross T head C, Fig. 1, for the purpose of easily unshipping and raising it out of the water by means of the lifting bearings D D, when it is not required for steaming. The wear of the brass bush is very uncertain and various, and has been found to amount to as much as an inch in thickness in the course of a few months.

The author of this paper, having had his attention forcibly called to the subject by these circumstances, made a series of experiments on different materials as bearing surfaces, and the final result has been the adoption of wood bearings for the screw shafts, and these have now come into general use for this particular application with complete success.

The method in which the wood is employed is shown in Figs. 2 and 3: the ordinary brass bush E has longitudinal dovetailed grooves formed on its face, which are filled with strips of hard wood F F; lignum vitæ has been generally used. The strips of wood are about 2½ inches wide, with a space of about ¾ inch between each, and stand out ¼ inch from the surface of the brass; water is kept constantly flowing between the strips along the shaft, and forms the only mode of lubrication, and this is found to prevent all tendency to heating or wearing of the journals.

Besides a large number of merchant vessels, upwards of 200 of the last new ships constructed for H. M. service have been fitted with wood bearings, and all former vessels are being altered to the same plan as fast as opportunities will permit. As far as present experience has gone, neither the wood nor the journals appear to suffer any appreciable amount of wear or deterioration after many months' continued exposure to the action of the water.

The "Himalaya," of 3500 tons and 700 horse power, furnishes perhaps the best practical proof that can be adduced of the durability of the wood bearings. This ship was fitted in the first instance with the usual metallic bearings, but the wear was of so serious a nature as to induce the proprietors of the vessel to adopt the improved plan almost immediately after the author's discovery of its utility. The "Himalaya" being shortly afterwards purchased by the government, was employed as a transport, and during the first 10 months of her service she steamed 20,000 miles without exhibiting the slightest signs of wear in those parts which had previously given so much trouble. The screw of the "Himalaya" weighs upwards of 11 tons, and is not fitted with the means of raising it out of the water; and consequently, having no after bearing, the whole weight in addition to the projecting portion of the shaft is carried by the stern bush alone.

H. M. steam sloop "Malacca," of 200 horse power, also furnishes good evidence of the advantages of wood over brass and other metallic bearings. This vessel gave similar trouble to the "Himalaya," as long as it was fitted with brass bearings; but when last examined, since the application of the wood bearings, it had run over a still greater distance than any that it had accomplished previous to the use of them, without exhibiting the least signs of decay or want of adjustment in any of the bearings. The bearings had been fitted with lignum vitæ as a leading experiment for ships in the service of the Crown.

The ordinary brass bearings of screw shafts are made very long in proportion to their diameter, so that the pressure on them is only about 60 lbs. per square inch when the journals are in contact throughout; but this pressure is considerably increased in practice, owing to the bearings being sometimes thrown out of line by the straining of the vessel.

In the wood bearings, the surface is reduced more than one fourth by the spaces left between the strips of wood; but it appears from the results of working that 1-10th of the area of bearing surface is sufficient with wood as compared with brass. The wood bearings are found to stand a working pressure as great as 2,000 lbs. per square inch; and in some experiments made to ascertain the point at which abrasion would commence, a pressure of 8,000 lbs. per square inch was sustained without producing abrasion; whereas brass on an iron bearing at a pressure of 200 lbs. per square inch was found to cut directly, whether lubricated with oil or water, and failed quickly by the rapid cutting or abrasion.

The experiments which led the author to the adoption of the wood bearings were made with the apparatus shown in Figs. 4 and 5, consisting of a wrought iron axle G, $1\frac{1}{2}$ inch diameter, running in wooden bearings at each end of a trough of water H, 2 feet long. The axle was immersed wholly in the water, and driven by a pulley J on the outer end, at a speed of 700 revolutions per minute, representing a velocity of 260 feet per minute at the circumference of the axle, which corresponds with or rather exceeds the ordinary velocity of the journals of screw shafts. One half of the length of the axle K was covered with brass, the object of which was to try alternately the effect on brass and iron under precisely the same circumstances. A cylindrical bearing 1½ inches diameter and 2 inches long was turned on the centre of each portion of the axle, upon which were placed the experimental bearings of which the relative frictions were to be ascertained; and in order to prevent any source of error from friction in the fixed bearings at the extremities of the axle, two experimental bearings L L were used at the same time, placed close together side by side, one above and the other below the axle, and pressed against the journal in opposite directions by two weighted levers M M, having adjustable weights to regulate the pressure. By this arrangement, the axle was as it were suspended freely in the trough of water, having no material friction in the fixed bearings at the extremities.

The relative friction of the different materials under trial was measured by the rise of the temperature of the water in the trough in a given time, caused by the rotation of the axle, the quantity of water being exactly two cubic feet in each case, and at the same initial temperature. In estimating the pressure to which the bearings were subjected, 1 square inch of bearing surface was used, and the total weight on each bearing gave the pressure in lbs. per square inch.

The particulars of the experiments are given in the Table appended, and the general results obtained were as follows:—

Description of Bearing.	Pressure per square inch. lbs.	Time of Running.	Result of Experiment.
Brass on Iron	448	30 mins.	Little or no cutting.
Brass on Iron	675	1 hour	Cut and abraded.
Brass on Iron	4480		Seized and stuck fast immediately.
Lignum Vitæ on Iron...	1250	36 hours	No signs of wear; original slight scratch not worn out.
Box on Brass	4480	5 mins.	Not cut.
Lignum Vitæ on Brass	4000	5 mins.	No injury. This specimen is shown full size in Fig. 6.
Snake-wood on Brass...	4000	5 mins.	No injury. Shown full size in Fig. 6.
Cam-wood on Brass ...	8000	5 mins.	No injury. Shown full size in Fig. 7.

In the foregoing experiments, the principal object was the prevention of the serious evils attending the ordinary bearings of screw shafts; and the circumstances under which the experiments were conducted were therefore arranged to correspond as nearly as possible with those experienced in the actual working of ordinary screw shafts; the experimental axle was wholly immersed in salt water, and was driven in all cases at a speed equivalent to that of screw shafts on the largest scale.

The result obtained from these experiments was so definite and satisfactory, that arrangements were immediately made for the application of the wood bearings to the screw shafts of H. M. ships, and these have in every instance succeeded beyond expectation. The author proposes however to resume the experiments on the first opportunity, in reference to the application of the wood bearings to other purposes in machinery, and he will be happy to communicate the results to the Institution on a future occasion.

The general results at present appear to point to the use of a plentiful supply of water, to carry off the heat caused by the friction of the bearings; and in the cases where this can be accomplished thoroughly, so as to carry off the heat as fast as it is generated, a brass journal revolving in hard wood bearings is practically perfect, showing no perceptible wear under a much more severe pressure than is usually met with in machinery. The two rubbing surfaces appear in reality to run without any lubricating material between them, and the water acts merely as a conductor to carry off the heat as rapidly as it is produced.

One other application of the wood bearings may be mentioned, which has been practically tried and found very advantageous. The bearing which receives the thrust or propelling effect of the screw in the direction of the vessel's motion is formed of a series of collars on the shaft, running in corresponding grooves in the brasses, which have been found to wear very seriously, in a similar manner to the main bearings of the screw shafts. The thrust bearing of the "Himalaya," which is shown in Fig. 8, had the brasses worn away longitudinally nearly $\frac{3}{4}$ inch at each collar, and this was repaired by the engineer whilst out on the voyage, by putting in a set of rings of

TABLE OF EXPERIMENTS ON FRICTION OF BEARINGS.

September, 1854.

Description of Bearing.	Area of Bearing.	Total Pressure.	Pressure per sq. inch	Time of Running.	Result of Experiment.
	sq. in.	lbs.	lbs.	minutes.	
Brass on Brass	1/8	448	3584	15	
Box on Brass	1	560	560	10	Marks not out.
Box on Brass	1/8	448	3584	5	Not cut.
Box on Brass	1/8	560	4480	5	Not cut.
Box on Brass	1/8	560	4480	5	Not cut.
Box on Brass	1/8	672	5376		Cut and abraded; side grain.
Box on Brass	1/8	672	5376	5	End grain; not cut.
Lignum Vitæ on Brass	1	672	672	15	Scratches made with tip of knife not touched.
Lignum Vitæ on Brass	1/8	560	4480	5	Cut a little.
Brass on Brass (salt water)	1	448	448	30	Little or no cutting.
Brass on Brass (salt water)	1/8	448	3584	6	
Brass on Iron	1	448	448	5	Cut.
New Brass on Iron ...	1	560	560	10	Cut.
Brass on Iron	1	675	675	60	Cut and abraded.
Brass on Iron	1/8	560	4480		Would not revolve; seized & stuck fast immediately.
Babbitt's metal on Iron	1/4	400	1600	8	Rolled out sideways.
Kingston's metal on Iron	1/4	400	1600	6	Rolled out sideways.
Box on Iron	1	448	448	30	No perceptible wear.
Box on Iron	1/8	448	3584	19	
Box on Iron	1/8	448	3584	5	But little worn.
Lignum Vitæ on Brass	1	560	560	10	Mark not out.
Lignum Vitæ on Iron	1	1250	1250	2160	No signs of wear; original slight scratch not out.
Lignum Vitæ on Brass	1/4	1000	4000	5	No injury.
Snake-wood on Brass	1/4	1000	4000	5	No injury.
Cam-wood on Brass ...	1/8	1000	8000	5	No injury.

lignum vitæ as an experiment, filling up the worn space, as shown in the upper half of Fig. 8. The wood was merely sawn into half rings, the lower pieces being slipped in from above without lifting the shaft from its bearing. This plan answered completely, and no perceptible wear was found in the wood rings after the voyage home, the original saw marks not even being effaced; and the bearing proved so satisfactory, although only temporarily constructed, that the vessel has gone to sea again without any alteration. In this case the wood bearing was allowed to work most of the time with oil alone as a lubricating material.

Of the various kinds of wood that have been tried in the experiments, lignum vitæ appears to be very satisfactory, and nearly as good as any, and it has the practical advantage of being less expensive, and readily obtainable.

Mr. F. P. Smith stated that, in the unavoidable absence of Mr. Penn from illness, he had attended the meeting in his stead, and would be able to give any further explanation that might be desired upon the subject, as the experiments upon the wood bearings had been conducted under his own superintendence. He exhibited a number of specimens of bearings that had been experimented upon, consisting of different kinds of wood, and also of ivory, brass, and white metal.

The Chairman observed that the subject of the application of wood to the bearings of shafts was one of great importance, as the difficulty to be provided against in the shafts of propellers revolving under water was very serious, and although the use of wood for this purpose was not exactly new, it was still quite new in this particular application, and the mode of carrying it out was very effective and useful. The experiments that had been made appeared to have been carried hardly far enough to obtain complete results, and he thought they should have been continued beyond the limit of 8,000 lbs. per square inch, till abrasion of the wood took place, so as to ascertain the real point of failure of the different materials. He hoped the subject would not be allowed to rest with the application of wood to the bearings of screw shafts alone, but that experiments would be made with a view to the use of wood for other purposes, such as perhaps the journals of locomotives and railway carriages, and other bearings in machinery exposed to much wear, and requiring at present much repair.

Mr. Smith said that the experiments would have been conducted further, as had been suggested, had time allowed; but the bearings of the screw shafts in the war steamers that were under consideration were wearing away so fast, that Mr. Penn was glad to be able to arrive at a practical conclusion at once, as to the mode of stopping the evil that had been the special object of the enquiry, particularly as the results of the experiments, so far as they had been carried out, had proved so much more satisfactory and definite than could have been anticipated. The pieces of wood that had been used for trial were apparently insignificant, and their small size might cause the experiments to be looked upon as not sufficiently practical; but it had been found in the first trials that a pressure of 1000 lbs. per square inch on a piece of wood of 1 square inch area would not wear out the scratch of a pin, after running 24 or 36 hours; and the only available method at the time of increasing the pressure per square inch had been to reduce the size of the pieces of wood, retaining the same weights in the apparatus with which the experiments were made. The slips of wood of 1 inch length had accordingly been reduced in width to 1-4th inch, in the expectation that a few minutes would suffice to give a definite result, but no wear could even then be produced; the area was then reduced to 1-8th square inch, and still no abrasion took place under a pressure of 1000 lbs., or 8000 lbs. per square inch; the experiment was limited to this pressure by the slipping of the strap upon the pulley by which the shaft was driven. The little bit of wood used in this experiment had been left running for 3 hours at a speed of 260 feet per minute, and had been tried in both fresh water and salt water, the latter salter than the sea, with no difference in the result. A brass bearing that had been driven at the same speed had been cut immediately at a pressure of 220 to 230 lbs. per square inch, so remarkable was the difference between wood and brass; and Babbitt's soft metal, Kingston's metal, and other mixtures, had also been tried, but were not capable of working under a pressure at all approaching that admissible with the wood bearings. Several soft woods had been tried, all of which stood well; and among them poplar, which was a very soft wood, stood a heavy pressure with very little wear. It was the intention of Mr. Penn at the earliest opportunity to try a second series of experiments, in a more complete manner, carrying them out if possible to the limits in each case of the material tested. The test to which the wood bearings had been subjected in the "Himalaya" was the severest to which it was possible that they could be exposed in practice. In this vessel, the screw was made without any provision for drawing it up, and had accordingly no after-bearing in the rudder post; the weight of the screw was 11¼ tons, or 13 tons with the overhanging portion of the shaft, and the bearing being 18 inches diameter and 4 feet length, the pressure was about 60 lbs. per square inch. The wood was applied in 20 strips, each 4 feet long and 3 inches wide, fitted close together round the inner circumference of the bush, the edges being bevilled so as to leave a groove nearly 1 inch wide between each of the strips of wood, for the water to flow through. After running 20,000 miles with the wood bearings, the vessel had occasion to change her screw, thus affording a good opportunity for examining the condition of the bearings, and it was found that the total clearance of the shaft in the bearing did not amount to 1-8th inch at the top, including the clearance which there must have been when originally fitted. The "Malacca" also had run 30,000 miles without any signs of wear in the wood bearings.

Mr. James Brown enquired whether the wood bearings had been applied to any rubbing surfaces, such as cross bar guides, in which the wear was caused by a reciprocating motion; and also whether any trial had been made of them for main shaft bearings.

Mr. Smith replied that they had not yet been tried for a reciprocating motion, but had been applied to the bearings of a crank shaft driving the machinery in Mr. Penn's factory; in this application, however, the wood had not proved superior to brass, and was attended with some inconvenience, as special provision was required to ensure a liberal supply of water to the bearings; otherwise the wood was speedily charred, and became useless. It had also been tried for the crank pin of the "Malacca," but was not found better than other bearings, such as soft metal; in such situations there was no means of maintaining the wood in a water bath to keep down the temperature, which appeared to be essential in the use of wood for bearings.

The Chairman observed that the hard wood specimens that were exhibited had got a fine polish upon their rubbing faces, and probably required to be kept always under water for that purpose. They appeared to have been dovetailed into the brass bush in every case, and this precaution would be necessary in order to prevent them from spreading laterally under great pressures.

Mr. Smith said that in the wood bearings considerable heat was generated with the very heavy pressures in the experiments, and the wood became so hot, although immersed in water, that it could not be touched with the hand, showing how rapidly the bearing would have heated, if the heat had not been continually carried off by the surrounding water. Oil had been tried instead of water, and gave no difference in the result, if used in a large quantity like the water, but it did not answer if applied only in the same quantity as to ordinary brass bearings, as there was then not enough to carry off the heat as fast as it was generated.

The Chairman observed that the complete immersion of the whole bearing in water appeared to be an essential element in the successful application of wood, and he suggested that in future experiments a thermometer should be applied direct to the wood or metal bearing under trial, in order to ascertain the exact temperature, as it was evident that this would be somewhat higher than that of the surrounding water. The same experiments might be made very serviceable to determine the relative friction of the various kinds of wood and metal tested. He enquired whether wood had been tried in different positions of the fibre, endways as well as lengthways of the grain.

Mr. Smith replied that it had been tried in all three positions, endways, in the direction of the fibre, and transversely to the fibre; but the experiments had not been continued long enough to test their relative value. He was inclined to think the end way of the grain was the best mode of applying wood, and this had been done by drilling a set of shallow holes in the bush, into which wood plugs were fixed; but this plan was objectionable in practice, as the wood plugs were liable to fall out when dry, and the readiest mode of application was flatways, that is, so that the friction would be transversely to the fibre; the latter method had been hitherto exclusively adopted in the wood bearings of screw shafts, and the wood could be readily and quickly applied to existing bearings, by planing out dovetailed grooves in the brass bush. In the experiments, the heating of the brass and wood had been measured by the rise of temperature of the water in the trough, and the results had been very marked; with the brass bearing, under a pressure of 200 lbs.

per square inch, the temperature of the two cubic feet of water rose to 120° or 130° in one hour, whilst with the wood bearing, under a pressure of 4000 lbs. per square inch, the temperature never exceeded 90° after any length of time, the heat beyond that limit being dissipated as fast as generated.

Mr. Hawkes remarked that he had had an opportunity of seeing the "Himalaya," immediately on her return from her first voyage, and on enquiring how the stern stuffing box of the screw shaft was kept constantly tight, was told that it was not found necessary it should be kept tight, and it was even preferable to have it loose, allowing the water to flow through freely; the vessel had indeed made part of the voyage with the stuffing box gland entirely removed, the water running through in a large stream, and being pumped out by the bilge pump, and the result had been successful in keeping down the temperature of the bearing. He enquired how much water was allowed to run through with the wood bearings, and whether any extra pump was generally required to remove it.

Mr. Smith said that the gland was frequently left loose to allow the water to flow through, about as much water running in as would fill an inch pipe; this water was ordinarily left to run into the bilge, and pumped out by the bilge pump, without the provision of a special pump. He might mention that in one instance, where the brass bearing was cutting severely, he had observed that the water running from the stuffing box was impregnated with fine brass scales, to such an extent that 7 oz. weight was caught in a couple of hours.

The Chairman remarked that the paper contained much interesting and important information, and he hoped Mr. Penn would continue the experiments under different circumstances of speed and pressure, and with dry wood as well as under water, and would communicate the further results to the Institution at a future meeting. He proposed a vote of thanks to Mr. Penn, and also to Mr. Smith, which was passed.

The following Paper, by Mr. Henry Woodhouse, of Stafford, was then read:—

DESCRIPTION OF AN IMPROVED CONSTRUCTION OF CROSSING.

In the crossings used in the permanent way of railways, an important portion of the expense of maintenance arises from the wear of the wing rails, caused by the wheels wearing a groove or recess on the upper surface of each wing rail at the part where they first strike it, when they lose the support of the main rail at the point of the crossing. The effect of this wear is to cause a drop of each wheel in passing over the crossing, producing a violent blow, and leading to more rapid destruction of the wing rails, which require to be taken up and renewed when worn into a groove at that part; the necessity for renewal occurs frequently in a short time, in situations where a heavy traffic passes over.

The object of the improved construction of crossing, described in the present paper, is to reduce the expense of these repairs, by constructing the rails of the crossings in such a manner, that when the wing rail is worn out at the part exposed to wear, it may be reversed, and the worn part replaced by another portion of the same rail; and also by making the check rails of the same form and length as the wing rails, so that when the latter are thoroughly worn out as wing rails, they can be used as check rails, what were previously the check rails being now used as wing rails.

The construction of the improved crossing is shown in the plan, Fig. 1, Plate 47. A A and B B are the rails forming part of the permanent way, and C C the rails of the crossing; D E are the wing rails, and F F the check rails. The wing rails and check rails are all of the same length, and are bent to the same angle, and consequently they are interchangeable, and the wing rails can be used as check rails, and the check rails as wing rails.

When the crossing has been some time in use, supposing, as is generally the case, that the traffic is mainly in the direction of the arrow, the wing rail E becomes injured by the action of the outer portion of the wheel tyres between the points G G, as shown by the black part, and in the cross section Fig. 2; when it is so much worn at that part as to require replacing, it is taken up and turned end over so as to bring the lower side uppermost, the end that was at H being brought to I, and the part below G G taking the place before occupied by the worn part. The crossing can now be used again till the part G G is worn out, and then by substituting the other wing rail D for E, the wing rail D can be used twice in the same manner. Each wing rail can thus be used four times, and when it is unfit for use as a wing rail, it can be put in the place of the check rail, and the check rails can then be used four times each, in the same manner as the wing rails previously. By this plan, the crossing may be renewed eight times with the same set of rails, before it is entirely worn out. In the ordinary crossing the wing rails cannot be interchanged with the check rails, and also, as the two ends of the wing rails are not similar, they cannot be turned end for end, and can be worn only in two places each. An ordinary crossing can consequently be renewed only twice with the same set of rails, before it is entirely worn out. The new crossing will accordingly last four times as long as an ordinary crossing. There are now 850 sets of the improved crossing in use on the London and North Western and other Railways.

The advantages to be derived from the use of the improved crossing are, simplicity of construction, and great saving in maintenance, both as regards labour and materials; the new plan is more particularly beneficial when the double headed rail is used, but it may be adopted with advantage for any other description of rail.

Mr. Woodhouse exhibited a model of the improved crossing, half size. He explained that the rails serving as check rails were worn only on the side of the head, and not at all on the top, and consequently when placed as wing rails they were as good as new rails.

The Chairman thought that the new crossing was a useful improvement on the ordinary construction, as it reduced the expense and frequency of repairs. He asked what actual saving was effected in the expense of the crossing.

Mr. Woodhouse answered that the new crossing would last four times as long as those on the ordinary construction, and therefore, taking the cost of a crossing at £8, the saving by the new plan was £24 per crossing, amounting to 75 per cent. saving on the total expense.

Mr. Sampson Lloyd enquired whether the new crossing was designed for particular angles, or whether it was applicable to any angle at which the two lines of rails might cross.

Mr. Woodhouse said it was applicable to all angles of crossing, from 1 in 4 to 1 in 12 (the usual limits); the only difference that was made in the rails was in the angle to which they were bent, which varied according to the angle of the crossing. The rails were bent cold, and thus required no trouble or expense in heating.

The Chairman proposed a vote of thanks to Mr. Woodhouse for his paper, which was passed.

The following Paper, by Mr. John Ramsbottom, of Manchester, was then read :—

ON AN IMPROVED SAFETY VALVE.

The growing tendency to use steam of higher pressure, and the greater care which this involves, have led engineers of late years to direct more particular attention to the design and construction of steam boilers, and also to their fittings; and amongst the latter the Safety Valve has received much consideration. Although there may be a difference of opinion as to the proportion which the working pressure of a boiler should bear to its absolute strength, it will doubtless be admitted, that the greater the certainty of a safety valve opening at the required pressure, and the greater its range of lift under a given excess of pressure, the less will be the excess of strength required. If a perfect safety valve could be made, that is, one which would absolutely prevent the boiler to which it was applied from being subjected to a higher pressure than that to which the valve was adjusted, it would of course be conducive in a high degree both to the safety and durability of such boiler.

The writer believes that the arrangement of safety valve now submitted to the meeting, shown in Plates 48 and 49, goes far to realise these advantages, the only rubbing parts being those upon the valves themselves in their seatings; and the small amount of friction thus occasioned may be entirely avoided by the substitution of spherical valves, if thought desirable. In addition to this, the range of lift for blowing off, owing to the non-intervention of levers between the valve and the spring by which it is loaded, and also to the dimensions of the spring itself, is about three times as great, under the same excess of steam pressure, as in the ordinary arrangement with lever and spring balance.

Fig. 1, Plate 48, is a vertical section, Fig. 2 a plan, and Fig. 3 a tranverse section of the valve. A A are two brass pillars, bolted upon the manhole cover B, and bored out at the upper ends to serve as seatings for the conical valves C C in the ordinary manner. The valves are loaded by the cross bar D, which is elongated at the end E, to form a handle, to enable the engineman to ascertain the working condition of the valves and the approximate pressure of the steam. To this bar is attached, at a point mid-way between the valves (when these are of equal size), and rather lower than the points which press upon them, the main spring F, which the writer prefers of the helical form, as shown. The spring is made of sufficient strength to resist the pressure upon both valves, and the pressure is regulated by the nuts G and the bridle H, the latter being made of such a length that the shoulder upon it shall be screwed home when the maximum load is put upon the valve. To provide against the valves being blown away in the event of the spring breaking, the lower part of the cross bar D is passed through a slot in the guard I, which in this arrangement is pivoted into the tops of the main pillars, and the shoulder upon the bridle H, Fig. 6, being unable to pass through the slot, prevents the valves being blown away. To compensate for the very slight difference that may arise in some cases (in the valves of large steam boats for instance), between the distance of the centres of the valves and the distance of the points of the cross bar, owing to the greater expansion of the former, the writer proposes to make one of the points K upon the cross bar loose; this is not necessary however, where the dimensions are small.

A similar arrangement may be adopted with the spring sunk in a well or recess L in the manhole cover, as shown in Figs. 4 and 5, so as to be more out of the way; and the chance of failure may be provided against by a cover plate corresponding to the guard I in Fig. 1. It is evident that under any form the valves constructed upon this principle cannot be easily tampered with; and a brass funnel may be placed over them in the ordinary manner.

The valves being equally loaded and of equal size will be bodily and simultaneously lifted together with the cross bar D when the steam pressure exceeds the proper limit, and the spring will be elongated through a range equal to the lift of the valves, and no more; so that, except when the engineman is testing the action of the valves, there is no movement in the joints of the apparatus, and therefore no friction.

A spring of $\frac{5}{8}$ inch round steel, and about 7 coils, is sufficiently strong to load two 3 inch valves to 80 lbs. pressure per square inch; and in order to load them to this extent, it will have to be stretched about $1\frac{3}{4}$ inch, or ·218 inch for each successive increase of 10 lbs. pressure per square inch.

Figs. 6 to 9, Plate 49, show a pillar arrangement, consisting of one entire casting B, which answers the part of a manhole cover. The steam passes up to the valves through the annular space between the well L and the outer casing. The spring F is lengthened to compensate for its reduced diameter, and is adjusted at the top in the same manner as in the plans previously described. This arrangement may be modified to suit the tops of square high fireboxes, by allowing the well L to project downwards into the boiler, in the same manner as shown in Fig. 4.

Figs. 10 and 11 show the application of the volute spring, which is placed in a shallow well L in the manhole cover and adjusted by the four nuts G G, which force down the small cover plate I, and so compress the spring until the requisite pressure is obtained; packings are then fitted between the cover plate and the manhole lid, to prevent any extra pressure being applied.

The spring may also be placed above the cross bar D, but the writer prefers to have it below, wherever practicable.

Mr. Ramsbottom exhibited a model, half-size, of a pair of safety valves with the spring between them, similar to those that he had at work, on the plan shown in Fig. 1.

The Chairman asked whether many of the new valves were at work, and with what results.

Mr. Ramsbottom answered that he had several of them at work, and they had proved quite satisfactory; they were found to be very sensitive, having such freedom of action as to get into a state of vibration producing in some cases a musical note when at the point of blowing off; and they allowed the steam to blow off more freely than other safety valves, under a given excess of pressure. The arrangement of the two valves under one lever was the same as in Mr. Fenton's Safety Valve, but the object had been to increase the lift of the valves, making it equal to the full extension of the spring, and also to dispense with the spring balances. The point of attachment of the spring was rather below the level of the two points bearing on the valves, so that in the event of one valve lifting before the other it was overloaded, the other being proportionately relieved; this tended to secure their simultaneous action.

Mr. H. Wright enquired whether any graduated scale was attached to the spring to indicate the pressure, as the ordinary spring balance was on this plan dispensed with.

Mr. Ramsbottom replied that there had not been any scale attached; the spring was adjusted originally to the maximum pressure intended, by measuring the amount of elongation under a given load, and in this way it was found it could be regulated by the adjusting screw to within 2 or 3 per cent. of the desired pressure. The valves were tested previous to being used, by comparing them with a pressure gauge attached to the same boiler.

Mr. Fenton observed that he had seen the new valve at work, and it appeared very satisfactory; the increased range of lift of the valves gave great freedom for the discharge of the steam, and prevented the pressure from rising.

The Chairman proposed a vote of thanks to Mr. Ramsbottom for his paper, which was passed.

The Chairman, in vacating the chair, said he could not relinquish his office of President without expressing the great satisfaction he felt at the progress the Institution had made, and the gratification that he had in looking back upon the number of valuable and interesting communications that had been laid before the several meetings at which he had presided during the last two years; and he trusted that the same cordial support which he had invariably received from the Members would be extended to his successor, and that equally important and useful papers would be forthcoming at the meetings of the present year.

The Meeting then terminated, and after the meeting, Mr. H. Woodhouse, of Stafford, exhibited a model, half-size, of an improved Switch.

In the evening, a number of the Members and their friends dined together, according to the annual custom, in celebration of the Ninth Anniversary of the Institution.

INSTITUTION OF MECHANICAL ENGINEERS.

BALANCE SHEET.

For the year ending 31*st December*, 1855.

	Dr.	£	s.	d.		*Cr.*	£	s.	d.
To	Balance 31st December, 1854	266	1	0	By	Printing and Engraving Reports of Proceedings .	105	5	9
,,	Subscriptions from 15 Members in arrear . . .	45	0	0	,,	Stationery and Printing	16	9	9
,,	ditto from 162 Members for 1855	486	0	0	,,	Office Expenses and Petty Disbursements . . .	26	11	0
,,	ditto from 2 Graduates for 1855	4	0	0	,,	Furniture and Fittings	8	14	10
,,	ditto from 7 new Members	35	0	0	,,	Travelling Expenses	7	19	2
,,	ditto from 4 Members in advance for 1856 . .	12	0	0	,,	Parcels	3	10	8
,,	Sale of extra Reports	33	4	3	,,	Postages	18	17	7
,,	Interest from Bank	5	9	7	,,	Salary	350	0	0
					,,	Rent and Taxes	113	15	6
					,,	Balance 31st December, 1855	235	10	7
		£886	14	10			£886	14	10

19*th January*, 1856.

(Signed) JOHN E. CLIFT,
SAMPSON LLOYD, } Finance Committee.

SUBJECTS FOR PAPERS.

STEAM ENGINE BOILERS, particulars of construction—form of heating surface—relative value of radiant surface in effect and economy—cost—consumption of fuel—evaporation of water—pressure of steam—density and heat of steam—superheated steam—steam gauges, high pressure and low pressure—explosion of boilers, and means of prevention—effects of heat on the metal of boilers, low pressure and high pressure—incrustation of boilers, and means of prevention—evaporative power and economy of different kinds of fuel, coal, wood, charcoal, peat, patent coal, and coke—moveable grates, and smoke-consuming apparatus, facts to show the best plan, and results of working.

STEAM ENGINES, expansive force of steam, and best means of using it—power obtained by various plans—comparison of double and single cylinder engines—combined engines—comparative advantages of direct-acting and beam engines—engines for manufacturing purposes—horizontal and vertical—condensing and non-condensing—governors—valves, bearings, &c.—indicator figures from engines, with details of useful effects, consumption of fuel, &c.—contributions of indicator figures for reference in the Institution.

PUMPING ENGINES, particulars of various constructions—size of cylinder and degree of expansion—strokes per minute, and horse power—number and size of pumps, and strokes per minute—comparison of double-acting and single-acting pumping engines—construction of pumps—plunger pumps—bucket pumps—particular details of different valves—application of pumps—fen-draining engines—comparative advantages of scoop wheels and centrifugal pumps, lifting trough, &c.

BLAST ENGINES, best kind of engine—size of cylinder, strokes per minute, and horse-power—details of boilers—size of blowing cylinder, and strokes per minute—pressure, and means of regulating the blast—improvements in blast cylinders—rotary blowing machines—indicator diagrams from air main and steam cylinder.

MARINE ENGINES, power of engines in proportion to tonnage—different constructions of engines—dynamical effect compared with indicator figures—comparative economy and durability of different boilers, tubular boilers, flat flue boilers, &c.—weight of machinery and boilers—kind of paddle wheels—speed obtained in British war steamers, in British merchant steamers, and in Foreign ditto, with particulars of the construction of engines with paddle wheels, &c.—screw propellers, particulars of different kinds, improvements in form and position, number of arms, material, means for unshipping, bearings, horse-power applied, speed obtained, section of vessel—iron and wood ships, details of construction, lines, tonnage, cost, &c.

ROTARY ENGINES, particulars of construction and practical application—details of results of working.

LOCOMOTIVE ENGINES, express, passenger, and luggage engines—particulars of construction, details of experiments, and results of working—speed of engines, cost, power, weight, steadiness—consumption of fuel—use of coal—consumption of smoke—heating surface, length and diameter of tubes—experiments on size of tubes and blast pipe—comparative expense of working and repairing—best make of pistons, valve gear, expansion gear, &c.

AGRICULTURAL ENGINES, details of construction and results of working—duty obtained—application of machinery to agricultural purposes.

CALORIC ENGINES, and Engines worked by Gas, Gun-cotton, or other explosive compounds—comparative consumption per horse-power per hour.

ELECTRO-MAGNETIC ENGINES, particulars and results.

WATER-WHEELS, particulars of construction and dimensions—form and depth of buckets—head of water, velocity, per-centage of power obtained—turbines, construction and practical application, power obtained, comparative effect and economy.

WIND MILLS, particulars of construction—number of sails, surface and form of sails—velocity, and power obtained—average number of days' work per annum.

CORN MILLS, particulars of improvements—power employed—application of steam power—results of working with an air blast and small stones—advantages of regularity of motion.

SUGAR MILLS, particulars of construction and working—results of the application of the hydraulic press in place of rolls.

SAW MILLS, particulars of construction—mode of driving—power employed—particulars of work done—best speeds for vertical and circular saws—form of saw teeth—saw mills for cutting ship timbers—veneer saws.

OIL MILLS, facts relating to the construction and working, by stampers and by pressure.

COTTON MILLS, information respecting the construction and arrangement of the machinery—power employed, and application of power—cotton presses, mode of construction and working, power employed—improvements in spinning and carding machinery, &c.

MACHINERY for manufacturing Flax, both in the natural length of staple and when cut.

ROLLING MILLS, improvements in machinery for making iron and steel—mode of applying power—steam hammers—piling of iron—plates—fancy sections—arrangement of rolls.

Stamping and Coining Machinery, particulars of improvements, &c.

Paper-Making and Paper-Cutting Machines, ditto ditto

Printing Machines, ditto ditto

Calico-Printing Machinery, ditto ditto

Water Pumps, facts relating to the best construction, means of working, and application—best forms—velocity of piston—construction of valves.

Air Pumps, ditto ditto ditto

Hydraulic Presses, facts relating to the best construction, means of working, and application.

Rotary and Centrifugal Pumps, ditto ditto ditto

Fire Engines, ditto ditto ditto

Sluices and Sluice Cocks, ditto ditto ditto

Cranes, ditto ditto ditto

Steam Cranes, Hydraulic Cranes, Pneumatic Cranes, ditto

Lifts for raising Trucks, &c. ditto ditto ditto

Lathes, Planing, Boring, and Slotting Machines, &c., particulars of improvements—description of new self-acting tools.

Wood-working Machines, morticing, planing, &c.

Toothed Wheels, best construction and form of teeth—results of working—power transmitted—method of moulding.

Driving Belts and Straps, best make and material, leather, rope, wire, gutta percha, &c.—comparative durability, and results of working—power communicated by certain sizes.

Dynamometers, pressure gauges, governors, construction and working.

Strength of Materials—facts relating to experiments on ditto, and general details of the proof of girders, &c.—girders of cast and wrought iron, particulars of different constructions, and experiments on them—best forms and proportions of girders for different purposes—best mixture of metal—mixtures of wrought iron with cast.

Durability of Timber of various kinds—best plans for seasoning timber and cordage—results of Kyan's, Payne's, Bethell's, and Burnett's processes, &c.—comparative durability of timber in different situations.

Corrosion of Metals by salt and fresh water, and by the atmosphere, &c.—facts relating to corrosion, and best means of prevention—means of keeping ships' bottoms clean—galvanic action, nature, and preventives.

Alloys of Metals—facts relating to different alloys.

Friction of various Bodies—facts relating to friction under ordinary circumstances—friction of iron, brass, copper, tin, wood, &c.—proportion of weight to rubbing surface—best forms of journals, and construction of axle boxes, &c.—lubrication, best materials, and means of application, and results of practical trials—best plans for oil tests.

Iron Roofs, particulars of construction for different purposes—durability in various climates and situations—comparative cost, weight, and durability—

roofs for slips of cast-iron, wrought-iron, timber, &c., best construction, form, and material—details of large roofs, and cost.

Fire-proof Buildings, particulars of construction—most efficient plan—results of trials.

Chimney Stacks of large size—particulars, form, force of draught, mode of building, cheapest construction, &c.

Bricks, manufacture and durability—hollow bricks, fire bricks, and fire clay—perforated bricks, cost of manufacture, and advantages—machines for brick making.

Gas Works—best form, size, and material for retorts—construction of retort ovens—quantity and quality of gas from different coals—oil gas, water gas, &c.—improvements in purifiers, condensers, and gas-holders—wet and dry gas-meters—pressure of gas, gas-exhauster—gas-pipes, strength and durability, and construction of joints—proportionate diameter and length of gas-mains, and velocity of the passage of gas—experiments on ditto, and on the friction of gas in mains, and loss of pressure.

Water Works—facts relating to water works—application of power, and economy of working—proportionate diameter and length of pipes—experiments on the discharge of water from pipes, and friction through pipes—strength and durability of pipes, and construction of joints—relative advantages of stand pipes and air vessels.

Well Sinking, and Artesian Wells, facts relating to.

Coffer Dams and Piling, facts relating to the construction.

Piers, fixed and floating, and Pontoons, ditto ditto

Pile-Driving Apparatus, particulars of improvements—use of steam power—Potts' apparatus—the compressed air system.

Dredging Machines, particulars of improvements—application of dredging machines—power required and work done.

Diving Bells and Diving Dresses, facts relating to the best construction.

Cast iron and Wrought iron Lighthouses, ditto ditto

Mining Operations, facts relating to mining—means of ventilating mines, use of steam jet and ventilating machinery—mode of raising materials—mode of breaking, pulverising, and sifting various descriptions of ores.

Blasting, facts relating to blasting under water, and blasting generally—use of gun-cotton, &c.—effects produced by large and small charges of powder.

Blast Furnaces—consumption of fuel in different kinds—burden, make, and quality of metal—pressure of blast—horse-power required—economy of working—improvements in manufacture of iron—comparative results of hot and cold blast.

Puddling Furnaces, best forms and construction—worked with coal, charcoal, &c.

Heating Furnaces, best construction—consumption of fuel, &c.

Converting Furnaces—manufacture of steel—casehardening, &c.

SMITHS' FORGES, best construction—size and material—power of blast—hot blast, &c.—construction of tuyeres.

SMITHS' FANS, and FANS generally, best construction, form of blades, &c., with facts relating to the amount of power employed and the per-centage of effect produced.

COKE AND CHARCOAL, particulars of the best mode of making, and construction of ovens, &c.

RAILWAYS—construction of permanent way—section of rails, and mode of manufacture—experiments on rails, deflection, deterioration, and comparative durability—material and form of sleepers, size, and distances—improvements in chairs, keys, and joint fastenings—permanent way for hot climates.

SWITCHES and CROSSINGS, particulars of improvements, and results of working—advantages obtained by steeling points and tongues.

TURN-TABLES, particulars of various constructions and improvements.

SIGNALS for Stations and Trains, and self-acting signals.

BREAKS for Carriages and Waggons, best construction.

BUFFERS for Carriages, &c., and Station Buffers—different construction and materials.

SPRINGS for Carriages, &c., buffing and bearing springs—particulars of different constructions and materials, and results of working.

RAILWAY WHEELS, wrought iron, cast iron, and wood—particulars of different constructions, and results of working—comparative expense and durability—wrought iron and steel tires, comparative economy and results of working—solid wrought iron wheels.

RAILWAY AXLES, best description, form, material, and mode of manufacture—comparison of solid and hollow axles.

The Council invite communications from the Members and their friends on the preceding subjects, and on any Engineering subjects that will be useful and interesting to the Institution;—also presentations of Engineering drawings, models, and books for the library of the Institution.

The communications should be written on foolscap paper, on one side only of each page, leaving a clear margin on the left side for binding, and they should be written in the third person. The drawings illustrating the communication should be on so large a scale as to be clearly visible to the meeting at the time of reading the communication, or enlarged diagrams should be sent for the illustration of any particular portions.

HOIST AND CUPOLA.

Plate 50

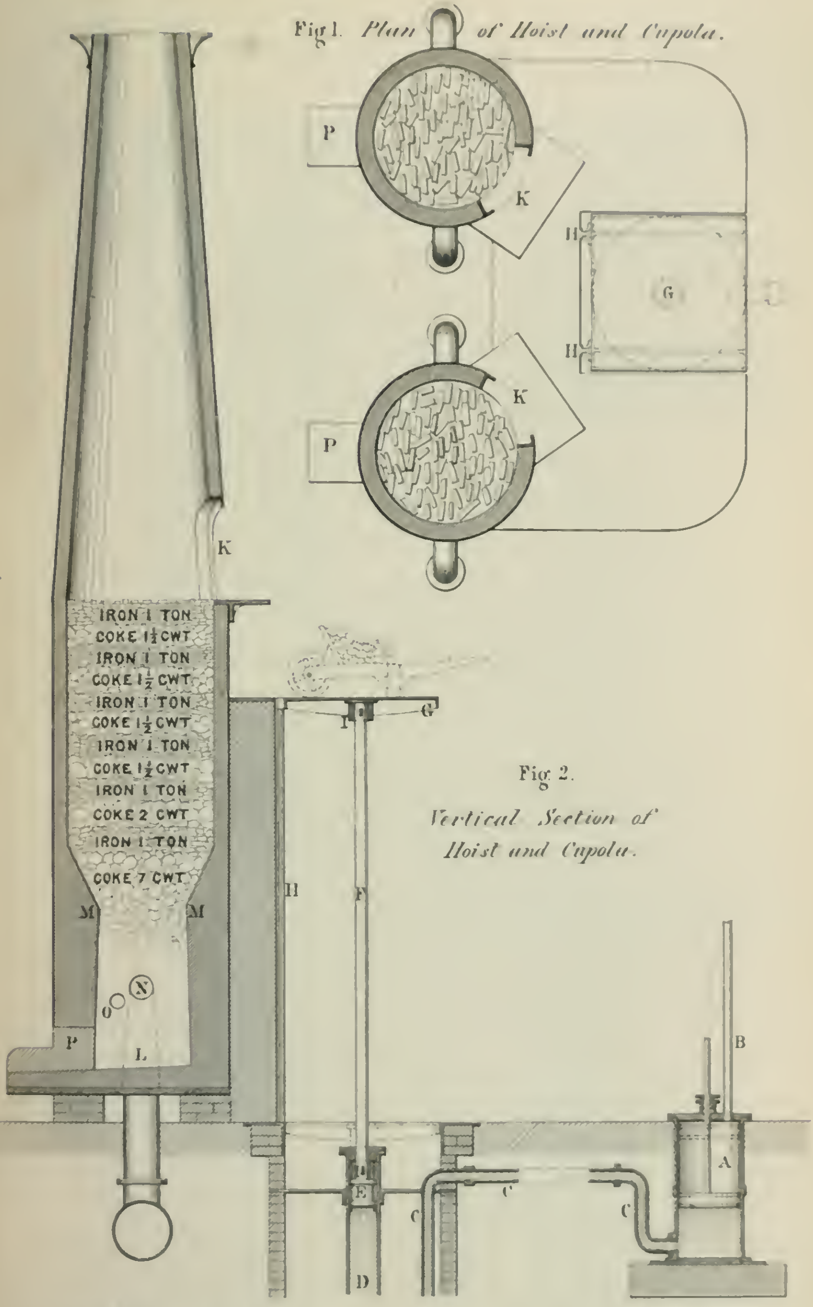


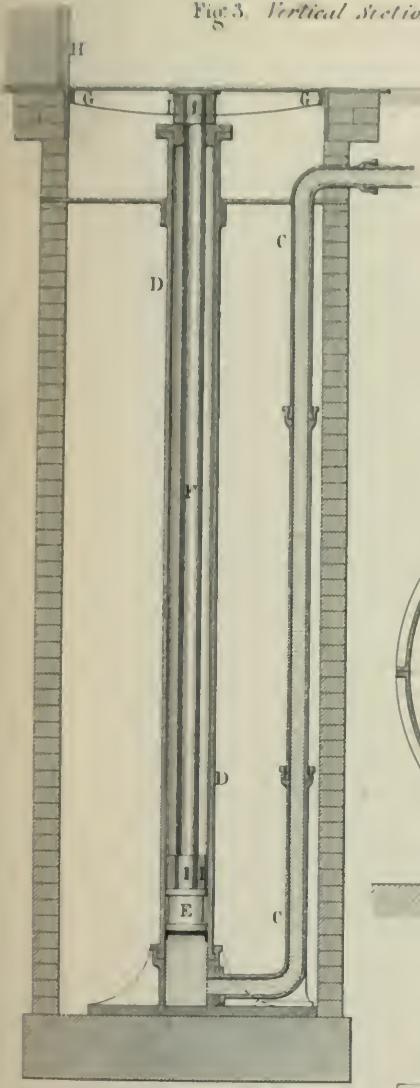
Fig 1. *Plan of Hoist and Cupola.*

Fig. 2. *Vertical Section of Hoist and Cupola.*

(Proceedings Inst M.E. 1856 Page 50)

HOIST AND CUPOLA.

Fig: 3. *Vertical Section of Hoist*



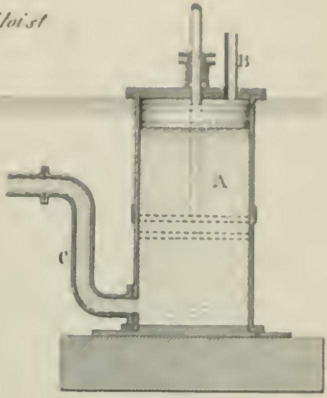


Fig: 4.
Vertical Section of Fan.

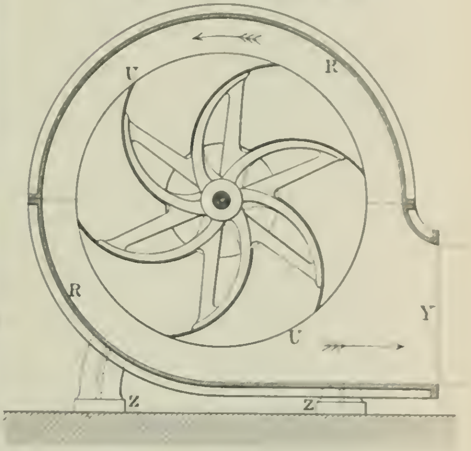
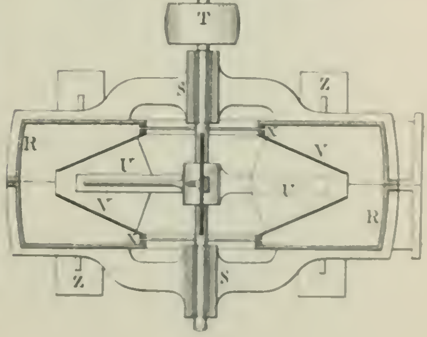


Fig: 5. *Sectional Plan.*



Scale 1/36th for Fig. 3.
Ins. 12 6 0 1 2 3 Feet

Scale 1/24th for Figs 4 and 5.
Ins 12 6 0 1 2 Feet

(Proceedings Inst M.E. 1856 Page 30.)

DOUBLE SLIDE EXPANSION VALVE

Plate 52

Fig 1

Plan at back of Valves

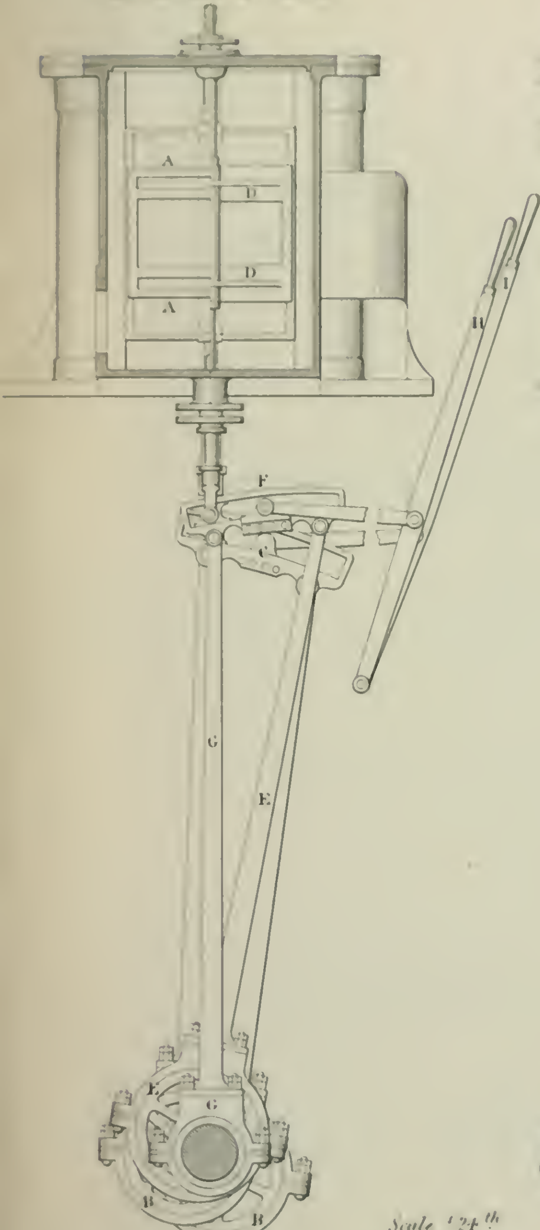
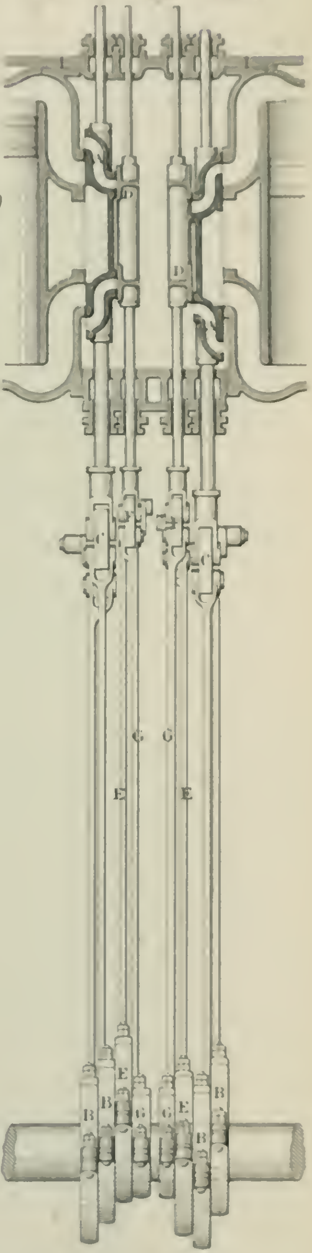


Fig 2

Section through Valves



Scale 1/24th

Ins 12 6 0 1 2 3 4 Feet

(Proceedings Inst M E 1856 Page 59)

VALVE PACKING

Fig. 1

Vertical Section of D Valve
with Ordinary Packing.

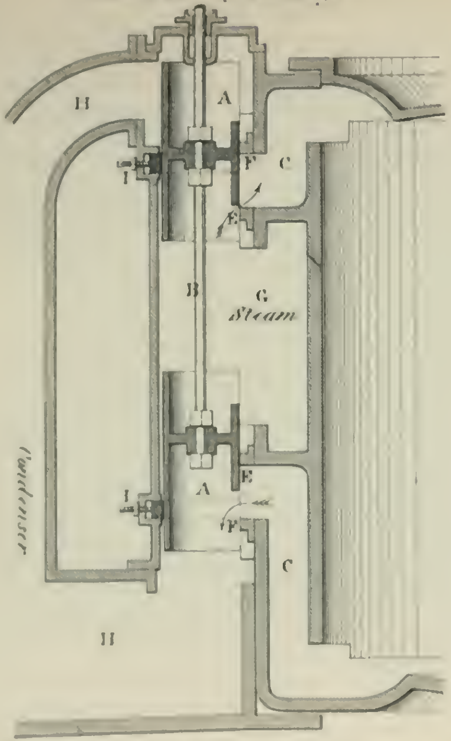


Fig. 2. Vertical Section of D Valve
with Improved Packing.

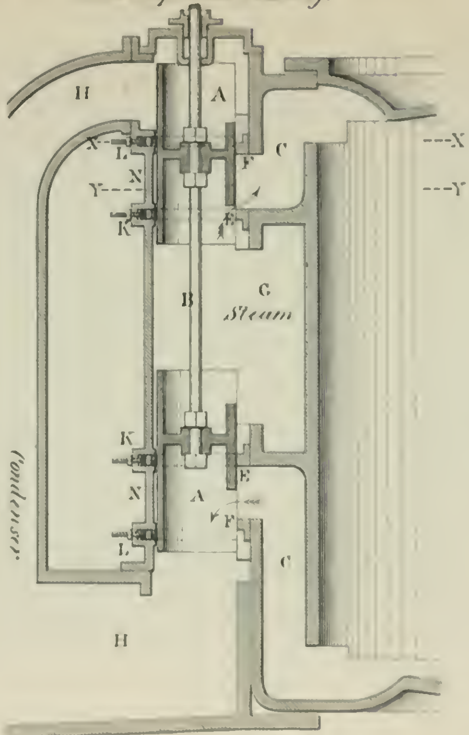


Fig. 3
Plan at XX
with Improved Packing

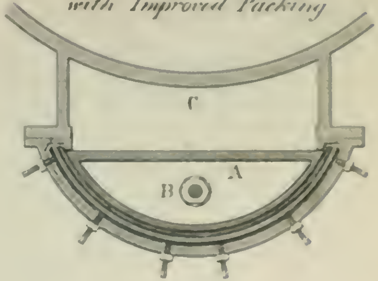
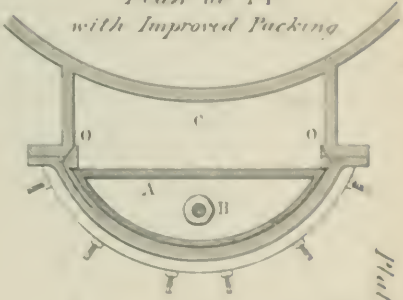


Fig. 4
Plan at YY
with Improved Packing



Scale 1/36th

Ins. 12 6 0 1 2 3 4 5 6 7 8 Feet

(Proceedings Inst. M. E. 1856. Page 62)

VALVE PACKING.

Fig: 5.
Elevation of Back of Valve Chest.

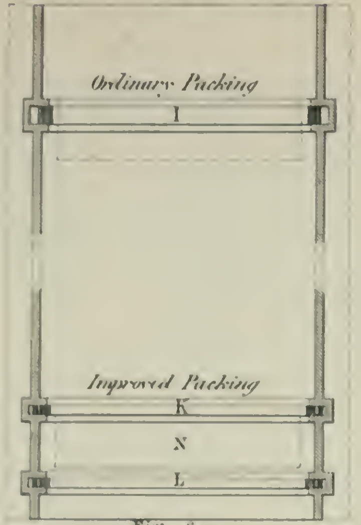


Fig. 6.
Elevation of Bars of Port

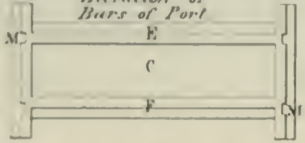


Fig. 7.
Single Slide Valve with Improved Packing.

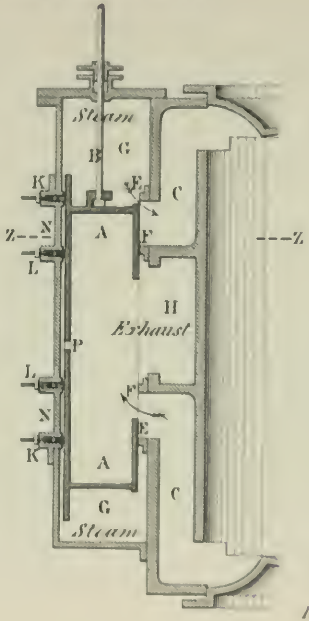


Fig. 8
Plan at Z.Z.
with Improved Packing

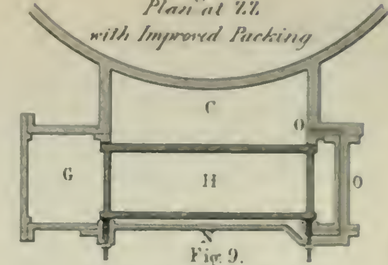
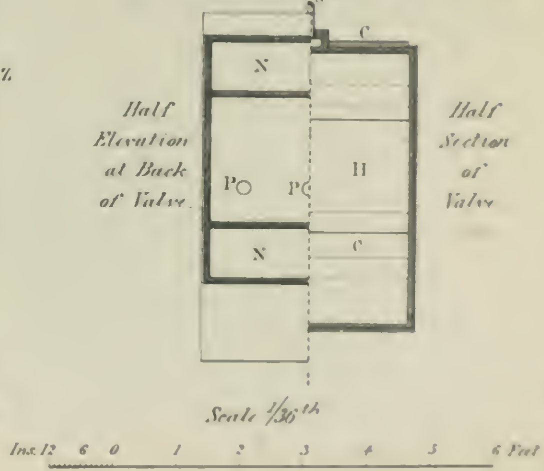


Fig. 9.



(Proceedings Inst M E 1856 Page 66)

STRAIGHT LINK MOTION

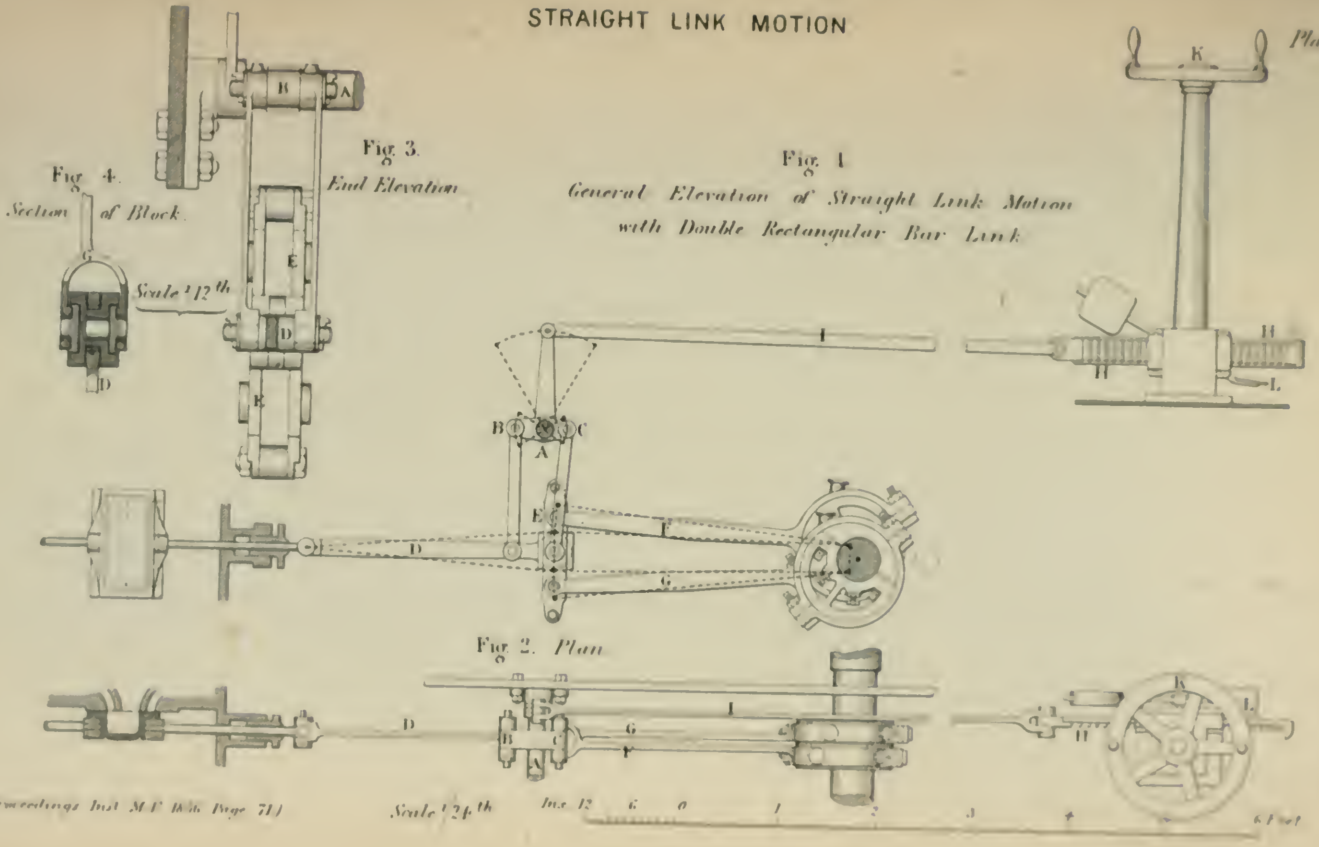


Fig. 1.
General Elevation of Straight Link Motion with Double Rectangular Bar Link

Fig. 2. *Plan*

Scale 1/24th

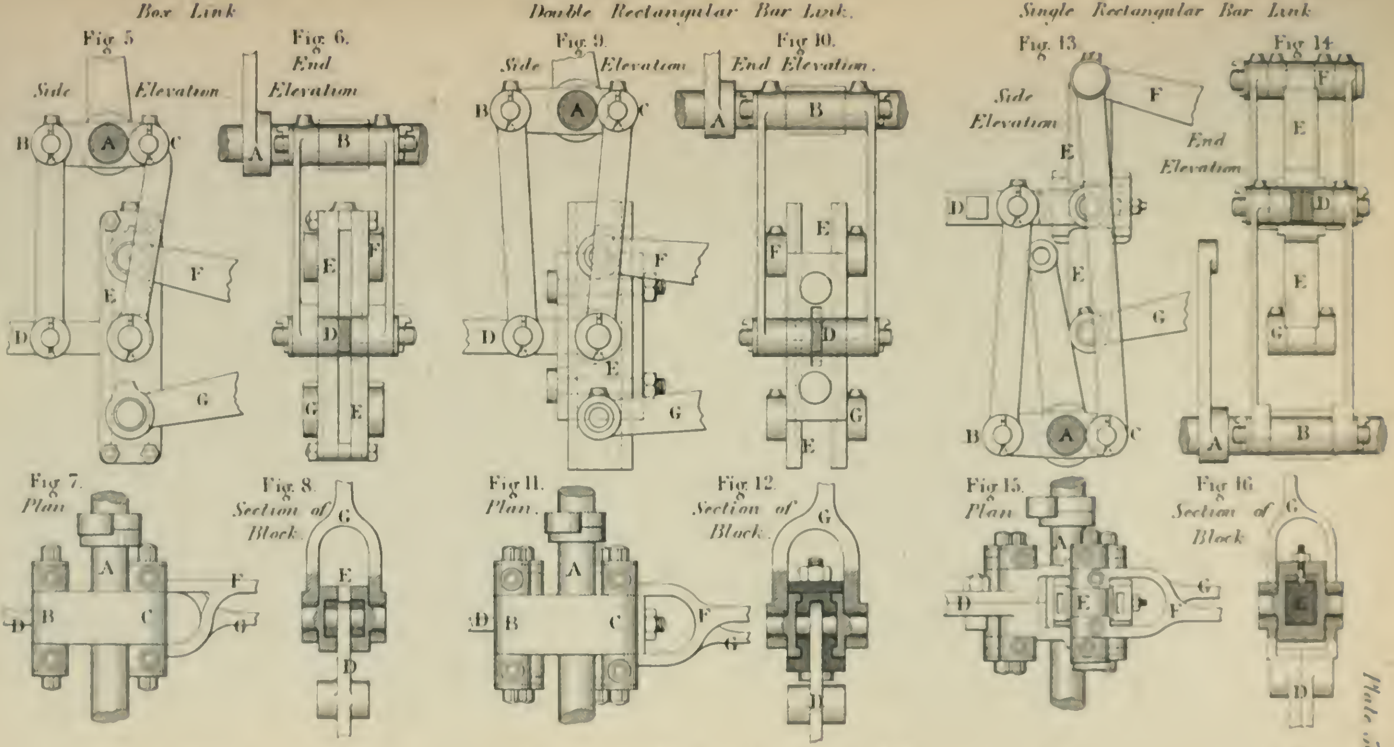
Fig. 3.
End Elevation

Fig. 4.
Section of Block.

Scale 1/12th

(Proceedings Inst. M.E. 1866. Page 71.)

STRAIGHT LINK MOTION.



(Proceedings Inst M E 1866 Page 71)

Scale 1/12th

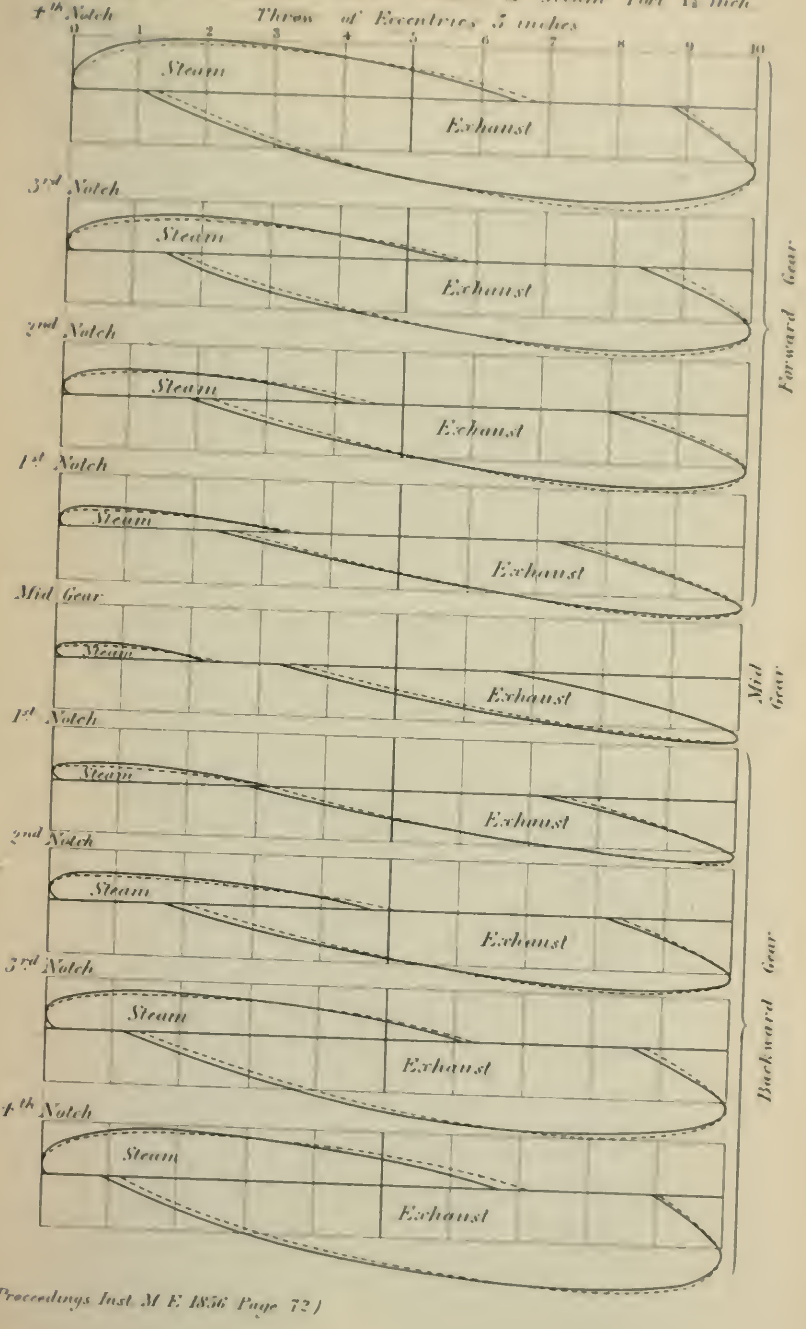
STRAIGHT LINK MOTION

Plate 57

Diagrams showing Distribution of Steam

Lap of Valve 1¼ inch   Width of Steam Port 1⅜ inch

Throw of Eccentrics 5 inches



(Proceedings Inst M E 1856 Page 72)

PROCEEDINGS.

April 30, 1856.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 30th April, 1856; Benjamin Fothergill, Esq., Vice-President, in the Chair.

The Minutes of the last General Meeting were read and confirmed.

The Chairman announced that the Ballot Papers had been opened by the Committee appointed for the purpose, and the following New Members were duly elected:—

MEMBERS.

Edward Ellis Allen,	London.
George Harrison,	Birkenhead.
Charles Markham,	Derby.
John Vernon,	Liverpool.
Frederick R. Wheeldon,	Bilston.
Henry Bickerton Whitehouse,	Bilston.
John Young,	Leeds.

The following Paper, by Mr. John Fernie, of Derby, was then read:—

DESCRIPTION OF AN IMPROVED FOUNDRY HOIST AND CUPOLA.

The object of the present paper is to describe some improvements in foundry plant, consisting of an improved Hoist, the invention of the writer, combined with Ireland's Cupola and Lloyd's Fan, which have been lately erected under the author's superintendence at the Britannia Foundry, Derby, and have given great satisfaction.

It is not intended, in this paper, to enter into any theoretical details; it is proposed merely to describe the practical working of the above appliances, and to consider them especially in regard to their economical results. The fan, hoist, and sand and loam mills, are all driven by a small high-pressure engine and boiler, put up at the same time as the other plant. The steam is got up at 8.0 a.m. to work the hoist. The blast is put on at 10.0 a.m., and kept up till 1.0 p.m.; the fire is then damped down till 4.0 p.m., when the fan is again put on, and runs till 7.0 p.m. The engine, consequently, works six hours per day; and the sand and loam mills are speeded to do their work in the six hours. The engine has a horizontal cylinder, 11 inches diameter, and 22 inches stroke, with 40 lbs. steam, and the necessary speed for the fan is obtained by belts. The quantity of coal consumed per day by this engine, whilst driving the fan and sand and loam mills, is 6 cwt., and the total consumption with the addition of the hoist is 7 cwt. per day for two 5 ton charges of iron.

The improved Hoist, used for charging the cupola, is shown in Figs. 1, 2, and 3, Plates 50 and 51.

Fig. 1, Plate 50, is a general plan of the hoist, as arranged with a pair of cupolas working together.

Fig. 2 is a vertical section of the hoist and cupola, showing the hoist raised in its highest position.

Fig. 3, Plate 51, shows the construction of the hoist in detail.

A, Figs. 2 and 3, is a steam cylinder, 20 inches diameter, fitted loosely with a piston, which has a range of 3 feet. Steam is supplied to the cylinder by the wrought iron pipe B, of $1\frac{1}{4}$ inch bore, by means of a three-way cock, which admits the steam or allows it to escape as required. The exhaust pipe has a cock at its far end by which the time of the descent of the hoist is regulated. The cylinder is sunk in the ground, with its top level with the surface, and is surrounded with non-conducting material. C C C is a 4 inch cast iron pipe, running from the bottom of the steam cylinder to the bottom of the hoist, a length of about 40 yards. D is the cylinder of the hoist, 12 feet 9 inches long, bored out from end to end to 8 inches diameter, and sunk in a well, the top being about 12 inches below the level of the ground. The piston or ram E has a cup leather screwed on at the bottom to serve as packing. F is the piston rod, formed for the sake of lightness of a wrought iron pipe

3½ inches diameter and about ¼ inch thick, carrying at the top the light cast iron platform G, 4 feet square, on which the barrow or wagon loaded with materials is run. The platform is steadied in its ascent by the guides H; I I are india rubber washers to break the shock of stoppage at top and bottom.

In working the hoist, the pipes C C C are first filled with water, till the piston of the steam cylinder A rises up to the top of the cylinder, the water being supplied through a wrought iron pipe of ¾ inch bore from the force pump of the engine that drives the fan. As there is always a little leakage at the cup leather of the piston E of the hoist, the capacity of the steam cylinder A is made larger than that of the hoist cylinder D to allow for this loss, being nearly in the proportion of 2 to 1. The barrow or wagon being run on the platform, the steam is admitted on the top of the piston, and the hoist begins to ascend. For the first stroke or two, condensation takes place pretty freely, and the hoist rises slowly; but the cylinder and water gradually get warm, and after a few strokes no perceptible condensation takes place. The hoist ascends the 10 feet in 20 seconds, when loaded with 9 cwt., and descends in 30 seconds, the steam being turned on and off by the engineman; the men at the hoist make signals when they want the hoist to ascend or descend, and it begins to move immediately, with scarcely any perceptible loss of time.

The hoist was originally calculated to lift 10 cwt. at a time, the pressure of the steam being 40 lbs. per square inch, and the diameter of the ram E 8 inches, making the total pressure upon it 18 cwt.; but it can take up conveniently only 9 cwt., and the weight of the platform, piston rod, and ram being about 3 cwt., there remain 6 cwt., or about 30 per cent., of which just so much is lost in friction as leaves an effective pressure sufficient to set the hoist in motion at the required speed. The writer has tried to balance part of the weight of the hoist by means of a counterbalance weight; but this was ultimately abandoned, as it was found that 7 or 8 cwt. was as much as it was convenient to lift at once, and the hoist did not come down so quickly as was required, when too nicely balanced. An improvement might be made on the hoist, by the addition of a condenser attached to the exhaust pipe; the platform might then be perfectly balanced, and the descent made sufficiently rapid by condensing the steam on the top of the piston.

The writer has made several experiments to ascertain the consumption of coal required to work the hoist alone; and has found that 1 cwt. per day, in addition to the usual quantity, 6 cwt., used by the engine, is sufficient to lift two 5 ton charges of iron per day. Before the hoist was used, as many as four labourers were employed during the whole day; but now two labourers fill up the cupola in two hours, their other time being spent in the foundry at cranes or carrying hot iron.

The hoist has now been at work 18 months, and during that time has lifted about 5000 tons 10 feet high. The only expense for repairs has been the cost of one new cup leather for the ram of the hoist, and one india rubber buffer ring.

The Cupola, which is the invention of Mr. Ireland, of Manchester, is shown in Figs. 1 and 2, Plate 50. It is capable of melting at the rate of 3 tons of iron per hour. The height from the floor to the top is 27 feet, and from the floor to the level of the charging door K 12 feet 6 inches. The shell is parallel from the ground to the charging door, and thence it gradually tapers up to the top. The outside diameter is 4 feet 6 inches in the cylindrical part, and 2 feet 6 inches at the top. The inside diameter is 2 feet 6 inches at the bottom of the crucible, on the cupola hearth L, contracting to 2 feet 3 inches at the springing of the boshes M M, and 3 feet 9 inches from the boshes to the charging door, whence it tapers to 1 foot 9 inches at the top. The height of the crucible is 4 feet 3 inches, and of the boshes 1 foot 8 inches, and the height from the boshes to the charging door is 6 feet 3 inches. From the top of the boshes to the top of the cupola the lining is formed of a single thickness of firebricks, which is quite sufficient, as practically there is found to be very little wear above the top of the boshes. The centre of the blast hole N is 2 feet from the bottom of the cupola, and the hole is 9 inches diameter, to admit a 7½ inch tuyere. O is a slag hole, 5 inches diameter, the top of which is level with the bottom of the tuyere hole. P is the tapping hole, which is made in the usual manner.

In charging the cupola in the morning, a small fire is first made at the bottom, as in the old cupola, and then 7 cwt. of coke is put in. The top of this should be carefully levelled, which is easily done in throwing in the last few skips. On the top of the coke 1 ton of iron is thrown in, the pigs being broken into three or four pieces each, which are thrown on with their length parallel to the direction of the blast, as shown in the plan, Fig. 1, leaving a space immediately over the tuyeres for the scraps that are to be melted. The next charge is 2 cwt. of coke, the top of which being levelled as before, 1 ton of iron is again thrown in, the pig ends lying in the direction of the blast as in the first charge, and the scraps are added over the tuyeres. The next charge is 1½ cwt. of coke, then 1 ton of iron, and these charges are repeated till sufficient metal has been laid on. The cupola is ready for blowing as soon as it is charged up to the door, as shown in the figure; it then contains 6 tons of metal, and 15 cwt. of coke, or 2½ cwt. of coke per ton of iron. The first charge in the afternoon is rather less than that in the morning; a portion of the coke used in the morning is saved, and the cupola being still warm, less is required at starting. The first charge is 5 cwt. of coke, after which the charging is the same as in the morning, giving a consumption of about 2⅙ cwt. of coke per ton of iron. Hence the mean consumption for the whole day is about 2⅓ cwt. of coke per ton of iron. The charge of flux consists of ½ cwt. of Derbyshire spar added on the top of the second and fifth charges of metal, the same being added at every third charge of metal afterwards. The slag hole is kept open nearly all the time of blowing, and has a spout from it, running off into a small wagon.

The repairing of the cupola is done every other day; the brick work just above the tuyeres becomes hollowed out by the action of the blast, and the cupolas are accordingly charged only every other day. When 24 tons of metal have been melted, amounting to two days' work, the repairs that are then ordinarily required take on an average 12 to 20 bricks, about ½ cwt. of fire clay, and 2 or 3 hours' labour. The cupolas on this construction at the Britannia Foundry have been nearly two years at work, and have given great satisfaction; they save nearly half the coke that was formerly burnt in the cupolas on the ordinary construction that were previously used in the same place. The bricks used are from Stourbridge, and the coke is from Elsecar.

The superiority of Ireland's cupola over the old construction consists in the shape of the interior, the height, and the perfect system of charging. Owing to the shape of the interior, the charges are kept up by the boshes M M alone, and as they gradually descend the incline, they are melted; consequently the only portions of the lining of the cupola that are subject to wear are the boshes and the sides of the crucible. The advantage of the height of the new cupola is evident on comparing it with some of the old cupolas, in which the height from the ground to the charging door seldom exceeds 8 feet, and in many cases is not more than 6 feet, instead of 12 feet 6 inches, as in the new cupola; consequently a great portion of the heat is lost at the charging door, which is retained in Ireland's cupola; and as all the heat has to pass up through the charges, the iron above is gradually warmed as it descends.

The mode of charging the old cupola could hardly be denominated a system. The quantity of the iron was estimated by the gross weight, or was guessed at; and the coke was seldom or never weighed. The iron was thrown on without any method, and the coke was added at the caprice of the man in charge of the cupola. If he thought the iron looked cold, an extra skip full or two of coke was thrown on, and he was not very particular whether he threw in more iron on the top of the coke or not. By the old method, the cupola was ready for blowing as soon as two or three charges had been put on, and a large portion of the heat was consequently lost; in Ireland's cupola the last charge must be thrown in before the blast is turned on, and the heat therefore passes from the first through the whole of the charges, so that very little is wasted. In the opinion of the writer, the quantity of coke used in this cupola is the minimum amount sufficient to melt the iron; for on two separate occasions when the blast was put on rather too soon, before the cupola was completely charged, there was great difficulty in getting the iron to run at all, and towards the end of the charge the front of the tapping hole had to be pulled down, and the iron was drawn out only partly melted. The heat rising from the lowest part of the charge, instead of being retained by the top charges, had been allowed to escape, thus causing the half melted state of the upper portion of the charge.

The cupola is blown by a Lloyd's Fan, shown in the vertical section, Fig. 4, and plan, Fig. 5, Plate 51. R is the outer case, cast in four parts, the two upper of which are bolted permanently together, and also the two lower. The horizontal joint through the centre admits of access to the internal parts without disturbing the foundations. S S are the bearings, and T the driving pulley. U is the internal revolving case, called the impeller, having sheet-iron discs V V fixed on the side edges of the blades. X X are turned brass rings fixed on the discs, and fitting up against cast iron rings bolted on the outer case, forming the centre opening through which the air enters the fan. Y is the discharge pipe, and Z Z the feet on which the machine stands, and by which it is bolted down to the foundations.

The difference between this fan and those of the ordinary construction consists in the form of the internal part U, which may be described as a revolving case, having six curved arms cast in one piece; on these are screwed curved sheet-iron blades, of the form shown in Fig. 4, on the outer edges of which are fastened the sheet-iron discs V V, previously mentioned. The total area of the openings at the circumference, as also the total sectional area of the internal passages at any distance from the centre, is equal to the areas of the two central openings in the sides of the outer case.

In the excellent paper on the Fan Blast, which Mr. Buckle read to this Institution, he entered into the origin of the objectionable noise which always attends the old fan. He found that by altering the area of the passage into the discharge pipe, by means of a segmental slide attached to the fan chest, the noise was very much reduced, when the area was equal to the area of the tuyeres. By lowering the slide till it was level with the underside of the tips of the vanes, nearly the same quantity of air was impelled as with the original opening, and the noise from the fan had nearly ceased. It therefore appears, as remarked in his paper, "that the less this opening is made, provided we produce sufficient blast, the less noise will proceed from the fan; and by making the top of the opening level with the tips of the vanes, the column of air has little or no reaction on the vanes."

It is not the intention of the writer to enter into the details investigated in Mr. Buckle's paper; but it may be observed, that the principles demonstrated in his experiments are carried out in this fan, although in a different manner. The discs V V prevent the reaction of the air on the sides of the blades, and the area of the tips being so much reduced, there is little surface for the blast to react upon at the tips, and hence the fan is almost noiseless. The pressure of blast at 1400 revolutions per minute, supplying two 7 inch tuyeres, is equal to 8 inches of water, that is 8 inches rise and 8 inches fall of the water in the gauge, making 16 inches total, or 9 ounces pressure per square inch; and at 2000 revolutions per minute, supplying two 8 inch tuyeres, the pressure is equal to 12 inches of water, or 24 inches total, equivalent to 14 ounces pressure per square inch. The first of these pressures, 8 inches of water, has always been found by the writer to be more than sufficient to melt from 2 to 3 tons of iron per hour.

It has been the design of the writer of this paper, in giving the results of his experience in the working of the cupola, fan, and hoist, to furnish to the Institution some practical data connected with the melting of iron, as economy is best induced by the communication of such experience. The coke consumed per ton of iron melted in the cupola may be safely set down at 2$\frac{1}{3}$ cwts. for ordinary working; but in continuous working, such as railway chair work, for instance, the average might be brought down as low as 1$\frac{1}{4}$ cwt. of coke per ton of iron, while the coal consumed for driving the fan and hoist, and sand and loam mills, should not exceed $\frac{3}{4}$ cwt. per ton of iron.

Mr. Fernie exhibited a specimen of a small Fan, made on the construction described in the paper.

The Chairman enquired whether he had made any comparative experiments with fans having blades parallel in width throughout, instead of tapered blades as in the fan described in the paper: in some fans that he was acquainted with, as in those by Schiele, of Oldham, near Manchester, the noise was prevented, though the blades were kept parallel, and there appeared to be some difference of opinion respecting the form of the blades.

Mr. Fernie had not had an opportunity of experimenting with fans having parallel blades, and consequently could not speak of the comparative advantages of the different forms; but he thought the casing round the blades gave a superiority over the ordinary fan with open blades.

Mr. Beyer asked whether the fan was noiseless at all speeds, and what was the highest speed at which it had been driven.

Mr. Fernie replied that there was no humming noise perceptible at any speed, and the clicking of the belt was the only sound to be heard; the fan was 3 feet diameter in the revolving part, and the highest speed at which he had seen it driven was 1400 revolutions per minute, the ordinary working speed being 1000 revolutions per minute.

Mr. R. Williams enquired whether the joint between the fan and the outer case did not require frequent oiling, as the friction would be considerable if it touched at all.

Mr. Fernie replied that no lubrication was required except for the journals, as the fan was made just to swim clear of the outer case; the journals had a large bearing surface, and were free from end play, preventing the fan from coming in contact with the outer case; no leakage of air was perceived at the joint, though it was not quite close. The revolving portion of the fan was light in construction, which was an advantage, the blades and discs being thin, and the arms also thin, being all cast in one piece.

The CHAIRMAN observed that from the investigations in Mr. Buckle's paper it appeared that the noise might be effectually prevented in fans having flat and parallel blades, if properly proportioned. In Schiele's fan the blades were more curved towards the outer extremities, and the air was drawn in on one side only, and expelled at the centre of the opposite side. In the fan recommended by Mr. Buckle the blades were flat instead of curved, and of equal width, any rebound of the air after delivery from the blades being prevented by making the outer case of a spiral form, increasing the space beyond the blades till it reached the size of the discharge opening.

Mr. H. WRIGHT confirmed what had been said of the absence of noise in Lloyd's fan; he had had one at work for some time, and it had proved very satisfactory. The fan was driven by only one strap, instead of two as frequently used, and he thought that plan preferable, as the tension of two straps could not be kept exactly equal.

The CHAIRMAN enquired whether any of the members present had made trial of the cupola described in the paper.

Mr. COCHRANE had one of Ireland's cupolas in use, and it had proved quite satisfactory and economical in fuel, if worked with complete regularity; he had had it at work for three or four years, but had found that it could not be worked so economically as had been stated, $1\frac{3}{4}$ cwt. to $1\frac{1}{2}$ cwt. of coke per ton of iron being quite the lowest amount to which he had succeeded in reducing the consumption, the cupola being charged with care in the manner described in the paper. He thought it a very good construction of cupola.

Mr. FERNIE said that Mr. Ireland stated he had reduced the consumption to $1\frac{1}{4}$ cwt. of coke per ton of iron, when the cupola was employed on regular continuous work, as in casting railway chairs; but in his own experience, with less regular work, he had not been able to get it lower than about 2 cwt., as stated in the paper.

The CHAIRMAN enquired how many of the cupolas had been erected, and what length of time any of them had been at work.

Mr. FERNIE replied that he believed there were about 90 of the improved cupolas in use, some of which had been at work for five years; he was not aware that there were any in that neighbourhood, but several had been put up at Manchester.

The Chairman proposed a vote of thanks to Mr. Fernie for his paper, which was passed.

The following Paper, by Mr. Francis W. Wymer, of Newcastle-on-Tyne, was then read :—

DESCRIPTION OF A DOUBLE SLIDE EXPANSION VALVE FOR MARINE ENGINES.

The writer, feeling convinced of the necessity of using expansion valves for the engines of screw steamers, applied the valves described in the present paper to the engines of the screw ship "Lord Raglan," one of the Tyne and Continental Steam Navigation Company's vessels, built on the Clyde.

The objects sought to be obtained by the application of these valves are, first, to afford a facility for using the full power of the engines when necessary for any length of time, the boilers being made large enough to supply a sufficient quantity of steam, even when cleaning the fires, and to allow of the necessary amount of blowing off at sea. Secondly, to provide an efficient expansion valve for reducing the power of the engines to any limit required, so as to gain an increased advantage in the results obtained from the consumption of a given quantity of fuel, compared with that which could be gained by the ordinary practice of wiredrawing the steam by the regulator valve. Thirdly, to provide the means of altering the degree of expansion, without at the same time altering the lead of the valve, or the time of exhausting from the cylinder into the condenser.

The valves are shown in Figs. 1 and 2, Plate 52; they are a modification of Messrs. Hawthorn's expansion valves for locomotive engines. The slide valve A of each engine is worked by a pair of eccentrics B B connected by a link C for reversing the motion in the ordinary way. A cut-off slide D is placed on the back of the slide valve A, through which the steam has to pass, and this is worked by a third eccentric E through an expansion link F. The lower end of the link F is connected to a concentric ring G on the axle, and is consequently stationary, so that by sliding the rod of the cut-off slide D to the lower end of the link its motion is stopped, and the valve remains full open throughout the stroke, the engines then working at their full power. The expansion link F can be adjusted by the lever H to cut off the steam at any point required in forward gear, and the combined action of the two slides gives a more prompt cutting off with less wiredrawing of the steam than in the case of the ordinary single slide valve. In backward gear the ordinary slide A alone is required to act, the reversing being effected by the lever I; the link C is used only for reversing, and can be fixed only in the extreme positions of forward and backward gear, the expansion being regulated by the cut-off slide D alone.

In the engines shown in the figures, the pistons have 30 inches stroke, and the main valves A are set to cut off at $22\frac{1}{2}$ inches or $\frac{3}{4}$ths from the commencement of the stroke. By moving the link F to any point between the centres of the two rods E and G, and thereby varying the length of travel of the expansion valve D, the steam may be cut off at any point between $\frac{3}{4}$ths of the stroke, when the rod G is in full gear and the engines are working at their full power, and $\frac{1}{4}$th of the stroke, when the rod E is in full gear and the expansion is carried out to the maximum degree.

This arrangement of valves has been in constant use on board the screw steamer "Lord Raglan" for the last nine months, during which time the vessel has run 14,000 miles, and the valves have given every satisfaction as to their efficiency, by the economy of fuel attending the use of them, and by their non-liability to derangement, and the ease with which their working can be regulated at any time according to the situation in which the ship may be placed, so as either to employ the full power of the engines, or to economize fuel for a long voyage by working expansively.

The following Table shows the results obtained from experiments at sea, including loss by blowing off necessary to keep the boilers clean, cleaning of fires, &c., incidental to steam navigation.

Consumption of Fuel of the "Lord Raglan" Screw Steamer, with the Double Slide Expansion Valve.

Expansion in percentage of Stroke.	Number of Strokes per minute.	Comparative Speed of Ship.	Loss of Speed of Ship.	Consumption of Coal per hour.	Per-Centage Consumption of Coal.	Per-Centage Saving of Coal.	Per-Centage Gain of Distance run by same consumption of Coal.
Per Cent.				Cwts.	Per Cent.	Per Cent.	Per Cent.
25	75	100	...	18	100	...	...
33	75 nearly	100 nearly	0 nearly	18 nearly	100 nearly	0 nearly	0 nearly
45	72	96	4	16	86	14	7½
50	69	92	8	13	72	28	22
58	67½	90	10	10	59	41	38

The description of coals used in the above trials was West Hartley.

In consequence of the absence of the vessel in the Crimea, the writer has not been enabled to give the general results up to the present time, as he had expected to do.

Mr. Wymer exhibited a model of the double slide valve, and showed the action of the cut-off slide with various degrees of expansion.

The Chairman observed that the double slide valve reminded him of the valve invented by the late Mr. Bodmer, which had a cut-off slide acting in a similar manner, and had been tried in several kinds of engines, including locomotives.

Mr. Beyer had used Bodmer's double valves formerly in several locomotives, and had found them work well as long as they were kept in good repair, but they did not stand well, on account of the great rapidity of reciprocation; the single valve and link motion was preferable for locomotive engines. The double slide valves would no doubt answer better for stationary or marine engines, where the motion was slower, as in the arrangement described in the paper.

Mr. Fenton remarked that the addition of the cut-off slide gave a better means for adjusting the degree of expansion; he asked whether it had an advantage in facilitating the exhaust.

Mr. **Beyer** explained that the exhaust remained always the same, and opened to the full extent for all degrees of expansion, the admission alone being affected by the cut off slide; and in this consisted the advantage of the double slide over the single valve.

Mr. **Miller** asked what metal was used for the valves and cylinder faces in the engines in which the trial of the new valves had been made.

Mr. **Wymer** replied that both of the valves were of cast iron, as well as the cylinder faces; they were not found to be worn after running 14,000 miles, but remained in a very good state; the vessel was at present abroad, and the valves had been examined in the week previous to her last sailing. He had at first used the ordinary link motion for marine engines, but had found a difficulty in preventing the engine from "knocking on the centres," in consequence of the increase of lead at high degrees of expansion, and the additional defect of variation in the exhaust that took place with the ordinary link motion; these circumstances affected large engines seriously, although they were not of importance in small quick-moving engines such as locomotives. By the use of the double slide valve that had been described the lead was kept the same and the exhaust remained constant for all degrees of expansion, the amount of expansion being regulated by the cut-off slide.

A vote of thanks was then passed to Mr. Wymer for his communication.

The following Paper, by Mr. Charles Beyer, of Manchester, was then read:—

ON WADDELL'S IMPROVED PACKING FOR THE SLIDE VALVES OF MARINE ENGINES.

The mode of packing the slide valves of marine engines, which forms the subject of the following paper, is the invention of Mr. Robert Waddell, of Liverpool, for many years chief engineer of several of the Cunard Mail Line of Steam Ships crossing the

Atlantic, who has been led by his practical experience of the serious evils and difficulties attending the present usual construction to devise a remedy, which simply and effectually accomplishes the desired object; and appeared to the writer a desirable subject to bring before a meeting of the Institution, as a piece of practical experience that might prove serviceable to the members.

In this country, the slide valve is generally used for marine engines, as well as for many other engines, and is particularly suitable from the simplicity of its construction and other advantages. The difficulties attending its use have arisen from the great pressure under which it has worked, and the consequent friction and wear of the rubbing faces. In large engines, such as those of the Atlantic steamers, in order to allow of the valves being worked by hand for reversing, it has been found necessary to remove a portion of the steam pressure from the back of the valve, and this has been done either by excluding the steam from a portion of the back of the valve, by means of packings acting between the back of the valve and the casing or valve chest; or by allowing the steam to pass round the portion of the valve between the ports, as is done in the D slide valve. The former method is principally used for short valves; but in marine engines, especially where the stroke of the piston is long, the D valve is mostly employed.

Double-beat valves are employed in the American line of Atlantic steamers, as well as in their river steamers generally, excepting for screw engines, where the great number of revolutions per minute requires slide valves. The double-beat valves are preferred to the D valve particularly in the river steamers, on account of the great increase that has taken place in the size of the engines and the pressure of the steam, and the difficulty that would arise in working the D valve with frequent stoppages of the engines. The double-beat valves of the Atlantic steamers are required to be very large, 19 and 18 inches diameter, and they are made each in two pairs, being eight valves for each cylinder, on account of the great size of the cylinders, which are 95 inches in diameter and 10 feet stroke. The large valve chests involve a loss of steam, and a practical objection is experienced in the difficulty of keeping the valves tight, from the expansion of the valve chests with the ribs and valve seats; and in rough weather, when the vessel is rolling and pitching, the valves do not come fair to their seats; from these causes it is understood that a trial is being made of a different form of valve for the purpose.

In the large steamers crossing the Atlantic, the D valve is constructed in a manner similar to that shown in the vertical section, Fig. 1, Plate 53.

The valve consists of two similar portions A A, fixed by nuts on the valve spindle B, at such a distance apart as to allow the steam ports C C to be near the ends of the cylinder, and consequently short, preventing the loss of steam that would occur with long ports. The ports are faced with brass bars E F, upon which the valve faces rub, and the valve has a throw of 18 or 20 inches. The steam enters the centre part G of the valve between the ports, and escapes to the condenser by passing out beyond the ends of the valve at H H. The back of the valve is made steam-tight by packing rings placed opposite the ports at I I, which prevent the steam from blowing right through into the condenser. The packing is generally formed of a flax gasket with a metal segment behind it, placed in a recess or port in the casing of the steam chest, and is set up to the back of the valve by set screws acting upon the metal segment.

The defects of this ordinary mode of packing the valves lie in the varying pressure of the valve faces upon the bars of the ports, which varies from several tons to nothing, and a pressure tending to separate the valve face from the bars. Taking the steam ports to be each $45\frac{1}{2}$ inches long by 10 inches deep, as in the large Atlantic steamers having 100 inch cylinders, and the packing ports I I at the back of the valve to be each $3\frac{1}{2}$ inches deep, then, when the valve is in the position shown in the figure, admitting the steam to the top of the cylinder, the pressure of the steam upon the entire area of the packing is unbalanced; or, taking the pressure of the steam at 20 lbs. per square inch above the atmosphere, there is an unbalanced pressure of 20 lbs. per square inch on an area of 159 square inches, giving a total pressure of 3,180 lbs. tending to force the valve off the bars against the packing all the time the port is open; and, consequently, the packing must be made by the set screws to exert constantly a pressure of 3,180 lbs. upon the back of the valve, in order to keep it up to the face of the port, and prevent the steam from blowing through into the condenser between the faces of the valve and port. On the other hand, when the port is opened to the condenser, and the valve in the position shown at the lower port in the figure, the pressure of the steam is unbalanced upon the difference between the combined area of the port and steam bar E together with the bars at the ends of the ports, and the area of the packing; or, taking the full vacuum at 12 lbs. per square inch, the extreme unbalanced pressure is 32 lbs. per square inch on an area of 412 square inches, giving a pressure of 13,184 lbs., to which must be added 5,088 lbs., the pressure of the packing, making a total pressure on the back of the valve of 18,272 lbs., or 8 tons, during the time of exhausting.

The very great pressure under which the valves work is necessarily attended with great wear both of the valves and port faces, requiring considerable expense in repairs. The valves are at the same time much more difficult to be worked by hand, requiring two men to handle them in small river steamers in starting the engine; and in large steamers four or five men are wanted for each valve, notwithstanding that the gearing is arranged to give a power of 20 to 1. In some instances, small steam cylinders have been tried for working the valves, in the place of hand gearing, but the writer is not aware what success has attended the change, and it is clear that no diminution of the wear of the valves would be thereby effected.

The most serious practical defect, however, attending the ordinary method of packing the valves, is not so much the great pressure under which they work, as the varying amount of the pressure per square inch between the rubbing faces at different parts of the travel of the valve. The difficulty arising from this source is experienced more particularly in large engines, although occurring in all engines using the slide valve, in proportion to their size, and where the valve is applied on a large scale the amount of the evil becomes very serious. It has been seen that when the port is open to the condenser there is an extreme pressure of 18,272 lbs. on the back of the valve; this is borne by an area of only 114 square inches when the port is full open to the exhaust; but when the port is beginning to open the pressure is borne by an area of 144 square inches; and the unbalanced pressure at that time is only about 16 lbs. per square inch, giving a total unbalanced pressure of 9,136 lbs.; hence the pressure between the rubbing faces is 63 lbs. per square inch when the steam begins to exhaust, and increases to 160 lbs. per square inch when the port is full open, and accordingly the friction on the exhaust side F of the face of the port is only 40 per cent. of that on the steam side E, or 60 per cent. less than the latter, and consequently the steam bar E is worn down more rapidly than the exhaust bar F. In a voyage across the Atlantic and back, the faces have been found to wear about 1-32nd inch off the straight on the steam side, and the wear would soon increase to 1-16th inch, if they are not re-adjusted. The consequence of this unequal wear is that, when the valve moves back again, closing the port, it is in effect rising up an inclined plane of 1-32nd inch, and a clear opening is left underneath, through which the steam blows straight into the condenser, causing waste of the steam and injury to the vacuum. The wear of 1-32nd inch in a port $45\frac{1}{2}$ inches long gives a clear opening of $1\frac{3}{8}$ square inches, through which the steam blows straight into the condenser at the beginning of exhaustion. When the opening to the condenser is closed, the wear of the steam side of the port permits the steam to act as a cushion upon the piston at the end of the stroke, and the same circumstance allows it to continue entering the cylinder after it is supposed to be cut off by the valve. The valve face is of course most worn on the exhaust side, and the total wear of both the valve and cylinder faces depends on the degree of expansion and the amount of lap.

The effects of the unequal wear of the valve and cylinder faces have been felt much more of late years, in consequence of the great increase in the size of marine engines, and the increased pressure of steam, which has been more than doubled in some cases for the purpose of saving fuel by working more expansively; and the trouble and expense that have arisen from this source have probably led in some instances to the abandonment of the slide valve. In order to obviate the evil as much as possible, it is necessary that the valve and cylinder faces should be re-adjusted as often as an opportunity offers, otherwise the loss of steam will be very great. In large steamers crossing the Atlantic, the valves are usually drawn on arriving at each port for the purpose of examining the packings, which often require to be replaced; and at the same time the valve and cylinder faces are adjusted. Two or three days are required each voyage for partially adjusting the valve and cylinder faces; and once a year they have to be thoroughly done up, back and faces, which occupies about a fortnight. So much straightening of the cylinder faces soon wears them down, and they require to be renewed in a few years.

The great loss of steam that takes place in this way, from the faces getting off the straight, often escapes observation, as the packings can be adjusted to the back of the valve only when in its tightest position, and whilst the engines are standing. In that position of the valves on the ports, there will be no escape of steam into the condenser, the valve faces being on the exhaust bars F F, and the packing then fitting close to the back of the valves, which have consequently the appearance of being tight, although loss of steam takes place as soon as they are put to work.

The improved mode of packing, the subject of the present paper, is shown in Figs. 2, 3, and 4, Plate 53, and consists in replacing the single packing ring I opposite to each port by a pair of packing rings K L placed opposite to the bars of the ports. The packing may be made in the ordinary manner with a gasket of flax or india rubber backed by a metal segment for the set screws to act upon; or a metallic packing ring may be used, and springs may be substituted for the set screws. As the strips of packing are never exposed to the pressure of the steam inside the valve, the pressure to which they are adjusted need be no more than sufficient to prevent the steam blowing through between the valve and the port face. The brass bars at the ends of the port have two small recesses M M, Fig. 6, Plate 54, in the outer edge of each, into which the ends of the segments or packing rings may enter as the packing wears down. This will make a tight joint, as the extreme positions of the valve in its travel do not uncover the recesses. The space N between the two rings, shown in the section Fig. 2, and the back elevation, Fig. 5, communicates with the port by a hole O, Fig. 4, at each end of the port, and by this plan there is always the same pressure on the back of the valve between the packings as in the port. The space N is made wider than the port by the amount of the width of one of the packing strips, and the extra area thus provided for steam pressure on the back of the valve replaces the area excluded from steam pressure by the packing strip K on the steam side. Hence this valve is really a balanced or equilibrium slide valve, and is not affected by the amount of pressure of the steam. The wear of the valve and cylinder faces and also of the packing is consequently very greatly reduced, the total pressure between the rubbing faces being no more than the amount required to keep them always in contact; and the wear that does take place is uniform, instead of being concentrated at a particular part.

The new mode of packing not only removes effectually the objections to the ordinary method, but is itself free from mechanical difficulties, whilst its simplicity renders it as easily applicable as the usual plan, and it may be readily applied to existing engines.

The new packing is applicable also to single slide valves, in the manner shown in Figs. 7, 8, and 9, Plate 54. The steam in this case is admitted at each end G G of the valve, and the eduction takes place from the centre H. The space N between the packings at the back of the valve communicates with the port by the passage O, Fig. 8; and the back of the valve opposite the exhaust port H communicates with the port through the openings P P, Fig. 9, so that the pressure upon the valve is completely balanced throughout, as in the large D valve described above.

The double-packed valve described above has been practically tried in a pair of large horizontal direct-acting engines of 500 horse power, constructed by Messrs. Randolf, Elder, and Co., of Glasgow, for the screw ship, "Columbian," of 2,500 tons burthen. The engines make 58 revolutions per minute, and under this severe test the working of the valves has proved very successful; when drawn after working for a period of about eight months, they appeared to have worked very smoothly, being in first-rate condition on the back and face. The packings were not found to be much worn, and did not require to be replaced; they had never needed to be tightened up during the voyage, and there was no appearance of escape of steam, as the condensers kept their vacuum for a considerable time after stopping the engines.

The advantages obtained by the new mode of packing the slide valves are:—a balanced valve, unaffected by the amount of pressure of the steam;—diminished friction and wear of the rubbing faces;—saving in consumption of fuel, by preventing leakage through the valve and diminution of vacuum in the condenser;—reduced weight and cost of valve gear, and better control over the engine, consequent upon the diminished power required to work the valves;—and lastly, saving in time, expense, and labour of maintaining the faces, packing, and gearing, in proper working order.

The Chairman remarked that the great amount of friction occasioned by the unbalanced pressure on the valves in large engines, with the ordinary mode of packing, rendered the subject one of much importance. He enquired what material had been found most suitable for packing the valves on the new plan.

Mr. Waddell replied that he preferred to use a brass packing, with a flax gasket behind it to allow of a slight yielding. The new mode of packing had an advantage over the ordinary plan, in admitting of the use of metal packing; in the ordinary plan it was necessary to pack the valves with some material softer than metal, on account of the irregular fit at the back of the valve, from the unequal wear of the face caused by the variable pressure to which it was exposed. The valves had therefore to be packed with a flax gasket, instead of a metallic packing, but in the new plan metallic packing might be used, in consequence of the valve being balanced, and the brass packings that had been tried had been found to answer well.

The Chairman observed that he had experienced the difficulty of keeping the packing tight in the ordinary D valve, and this difficulty would not attend a valve that was fully balanced.

Mr. Shelley asked whether the valves could be repacked without taking them out.

Mr. Waddell said that there were modes of doing so, but it was not necessary in general to make any provision for this purpose, as the valves were usually drawn after each voyage to examine the faces, and the packing was renewed at the same time. With the ordinary packing the unequal wear occasioned by the variable unbalanced pressure caused a rocking and beating of the valves on the bars of the port, when the packing became slack; even in small engines the knocking of the valves might be heard by placing the ear close to the cylinder, and in large engines it was heard at some distance. The defect of the variable pressure was less apparent in small engines, from the breadth of the packing strip being nearly equal to the port; but in large engines the area exposed to unbalanced pressure was so great that the variation in the total pressure became very serious. In the ordinary D valve the pressure was balanced between the ports, but the portion opposite the ports was left unbalanced, and this unbalanced pressure had not been perceptible with low pressure steam, but when high pressure steam was introduced with very large valves in the American vessels the D slide valve had to be abandoned on this account; were it not for this circumstance the D valve would be more economical than the double-beat valve. It should be observed that any pressure put upon the packing by the pinching screws was doubled in effect, by the valve having a rubbing face both on the front and back.

Mr. Miller enquired whether any experiments had been made to ascertain the saving in the power required to work the valves, when packed in the new manner.

Mr. Waddell replied that in the screw engines of the "Columbian," in which the new mode of packing had been adopted, there had been no means of disconnecting the valves to try them fully, but they were found to work easily with the hand-gear; there could be but little power required to work them, since the pressure between the rubbing faces was only the amount necessary to prevent the steam from blowing through, as in the case of pistons with metallic packing, and it was found that if two metal surfaces were well trued up, a very small pressure was sufficient to prevent the steam from penetrating between them. The ordinary packing occasioned a deceptive impression when examined, the valve being considered tight because no steam was detected blowing through into the condenser, when the engine was stopped for examining the packing; but at that time the valve was necessarily in the middle of its stroke and upon the exhaust bars of the ports, this being its tightest position, in which alone the packing could be adjusted; so that any leakage of steam could take place only into the cylinder, and no steam could escape into the condenser; but as soon as the engine was put to work, the steam began to leak through into the condenser, and a great loss of steam took place when the bars were worn.

The Chairman enquired what power was required to work the double-beat valves by hand in the large American steamers.

Mr. Waddell said that two men were generally required to each engine, though one man might be able to work the valves if well balanced, unless the stems were packed too tight; but it was found necessary that the valves should not be too nicely balanced in area, otherwise there was not sufficient effective weight to bring them fairly to their seats when the vessel was rolling, as they were sometimes lying at an angle of 45°, which reduced their effective weight so that they would not fall quick enough. The objections to the double-beat valves and the D valve had been found so serious in those large steamers, that in the engines of the last one, the "Adriatic," a new kind of cock valve had been introduced by the makers, Messrs. Stillman and Allen.

Mr. Fenton observed that a similar principle had been advantageously applied to steam hammers, by employing a cylindrical valve, balanced all round; he had some of them in use, and they were working satisfactorily.

The Chairman asked whether the area of the bar on the steam side of the port had been included in calculating the area exposed to unbalanced pressure in the ordinary valve.

Mr. Waddell said that the area of the steam bar and also of the bars at the ends of the ports had been taken into account as exposed to the pressure, because it could not be supposed that there was any steam pressure between the valve and the bars, otherwise the steam would blow through. If the bars were made wider, the wear would be diminished, by the increase in wearing surface, but the gain would be partly neutralized by the increase in the total unbalanced pressure, and this difficulty had led him to devise the new mode of packing.

Mr. Wymer fully concurred in the statement that had been made of the wear on the back and front of the ordinary D valve; and he considered the new mode of packing would cause a great saving, if it effected all that was stated.

The Chairman mentioned an instance that had occurred lately under his own notice, of a stationary engine working with the ordinary slide, where the engineman had been unable to stir the valve, and had been obliged to get a long lever to move it, involving a risk of accident from the difficulty of controlling the motion, and a serious accident might be occasioned by the valve sticking in this manner.

He proposed a vote of thanks to Mr. Waddell, which was passed.

The following Paper, by Mr. Alexander Allan, of Perth, was then read:—

ON AN IMPROVED CONSTRUCTION OF LINK MOTION FOR LOCOMOTIVE AND OTHER ENGINES.

The Link Motion used for working the slide valves of locomotive engines is constructed in two forms, termed the shifting link and the stationary link; in the former, the link is curved towards the axle with the radius of the eccentric rods, and is shifted up or down to reverse the motion of the slide valve, the valve rod being prevented from moving vertically. In the stationary link, on the other hand, the link is prevented from moving vertically, and the valve rod slides up and down in it, the curvature of the link being in the reverse direction, with a radius equal to the length of the valve rod. The action of the valves is similar in the two cases, except that with the stationary link the lead of the slide is maintained constant under all degrees of expansion, whereas with the shifting link the lead increases a little as the degree of expansion is increased.

The improved link motion, forming the subject of the present paper, is shown in Plates 55 and 56, and is in effect a combination of the shifting and stationary link motions, as both the link and the valve rod are moved at the same time, but in opposite directions.

Figs. 1 to 4, Plate 55, show the new link motion complete, with eccentrics, eccentric rods, and valve rod, as arranged for a tank engine.

Figs. 5 to 16, Plate 56, show various forms of the link motion, the reversing shaft being placed above or below the link according to convenience.

On the reversing shaft A are forged two arms B and C, on opposite sides of the shaft, the front arm B being connected with the valve rod D, and the back arm C with the link E, by means of suspending or sustaining links in the ordinary manner. As the arms B and C are on opposite sides of the reversing shaft, the vertical movements given to the valve rod, with the link block at its extremity, and to the link are in opposite directions; and their simultaneous movements, but in opposite directions, compensate for the curvature of the ordinary link, and consequently a straight link is substituted, the construction of which is simpler than that of the curved link.

The front arm B of the reversing shaft is made longer than the back one C, in such a proportion that, for any motion of the reversing shaft, the link E and the eccentric rods move through 3-5ths of the vertical space described at the same time by the link block and the valve rod D. On moving the gearing out of the position of midgear, shown in the figures, into the position of full forward gear, the link block moves upwards through a distance of 2½ inches, the effect of which is to give the valve rod an obliquity that is equivalent to shortening it up 1-10th inch. But at the same time the link moves downwards through a space of 1½ inch, and the obliquity of the forward eccentric rod F is thus diminished to an extent that is equivalent to lengthening it out 1-10th inch. Thus the shortening of the valve rod is exactly compensated for by the lengthening of the eccentric rod, and the valve will consequently remain stationary, causing the lead to be unaltered. Similarly, when the engine is thrown into the position of full backward gear, the same compensation takes place between the valve rod and the backward eccentric rod G, and the valve remains stationary. Hence it appears that, as far as regards the positions of full forward and backward gear and of midgear, the proper form for the link must be straight instead of curved. In order that the lead may remain constant in the same manner in the intermediate positions of gear, the correct form of the link ought to be two equal curves, concave towards the valve rod, having their extremities in the same straight line with the centre of the link, the curvature amounting to not more than about 1-32nd inch, for the dimensions of gearing shown in Fig. 1. The error arising from making the link straight, instead of curved in the above manner, causes therefore a total variation of not more than 1-32nd inch in the lead of the valve, and the lead may therefore be considered practically constant, at the same time that the straight form of link has an advantage in simplicity of construction, and more especially in facility of repairs.

The vertical movement of the link being 3-5ths of that of the link block, the total vertical movement of the link in reversing is therefore only 3-8ths of that in the shifting link motion; and the vertical movement of the valve rod and link block is 5-8ths of that in the stationary link motion. The length of the reversing lever is thus proportionately greater, and an increase of power is obtained for reversing; and the expansion can be easily regulated with the full pressure of the steam on the valves. For the same reason less room is required for the gearing than in either of the ordinary link motions, and the boiler may be placed lower on the frame.

The valve rod being connected to the longer arm of the reversing shaft so nearly counterbalances the link and eccentric rods, which are connected with the shorter arm on the opposite side of the shaft, that balance weights or springs are dispensed with, and the total weight on the reversing shaft is thus much reduced; at the same time the torsion to which it is subjected is also much diminished, on account of the diminished length of the arms. The entire link motion is carried by the weigh shaft alone, and no suspending rods from the boiler or framing are needed, the only fixings required being those of the reversing shaft, which may be placed above or below the link, according to convenience.

The results of the working of the new link motion are shown in the diagrams, Plate 57, taken from a Goods engine fitted with the new motion, having cylinders 16 inches diameter and 22 inches stroke, and also in the Tables appended; from which it appears that the new motion is accurate in its working, having a practically constant lead, and causing a nearly equal distribution of the steam in both ends of the cylinder in forward and backward gear. In the diagrams, Plate 57, the full line shows the distribution of the steam for the front stroke, from the buffer plank towards the fire box, and the dotted line represents the distribution for the back stroke in the opposite direction.

An improved construction of link, adopted by the writer in connection with the new motion, is shown in Figs. 1, 3, and 4, Plate 55, and consists of two straight rectangular bars, joined together by pieces bolted in between them at each end; each bar has three pivots formed on its outer side, to the centre pair of which the suspending or sustaining links from the reversing shaft are jointed, the top and bottom pairs fitting in the eyes of the eccentric rods. The link block fits in between the bars forming the link, its sides being formed with flanges so as to grasp the bars of the link, and the wearing surfaces of the block are lined with steel, the bars of the link being case-hardened. The block is made in two portions, Fig. 4, to allow of readily connecting and disconnecting it from the valve rod, one portion being formed with a projecting pin, which fits into a corresponding hole through the other portion, so that the two parts move together in the link in the same manner as a solid block. By this means a large wearing surface of all the working parts is obtained, particularly of the block; and when worn out of truth, the link may be ground straight again, and the block may be made up by inserting a small strip of brass or tin behind the steel liners.

The link and block may also be made in the same manner as the ordinary box link, as shown in Figs. 5 to 8, Plate 56; but the construction above described is preferable, from its simplicity and the greater facility which it affords for examination and repairs.

Another form of the double rectangular bar link is shown in Figs. 9 to 12, in which the two bars forming the link are not connected together by bolts or any other fastening, but the link is left open at both ends; the block is made in two portions, Fig. 12, in a manner similar to that already described, and is retained in its position by flanges formed on the bars of the link, as in the ordinary box link.

TABLE I.

Distribution of Steam by Straight Link Motion.

Stroke of Piston ... ... 22 inches.
Outside Lap ... ... 1 inch.
Inside Lap ... ... Line and line.
Steam Ports ... ... $1\frac{1}{4}$ inch × 12 inches.
Exhaust Port ... ... $3\frac{1}{4}$ inches × 12 inches.

Number of Notch.	Travel of Block in Link.	Lead of Slide.		Travel of Slide.	Total Opening of Slide to Steam		Point of Cutting off.		Exhaust opens and Compression begins		Period of Expansion.		Period of Compression.	
		Front Stroke.	Back Stroke.		Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Forward Gear 4	$\frac{7}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$4\frac{9}{16}$	$1\frac{3}{16}$	$1\frac{3}{8}$	79	78	93	92	14	14	7	8
Forward Gear 3	$\frac{3}{8}$	$\frac{1}{4}$ full	$\frac{5}{16}$	4	$\frac{7}{8}$	$1\frac{1}{8}$	71	70	91	88	20	18	9	12
Forward Gear 2	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{7}{16}$	$\frac{5}{8}$	$\frac{13}{16}$	56	58	85	83	29	25	15	17
Forward Gear 1	$\frac{1}{4}$ full	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{15}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	34	40	74	72	40	32	26	28
Mid Gear.........0	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{5}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	15	19	55	56	40	37	45	44
Backward Gear 1	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$2\frac{3}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	25	25	65	64	40	39	35	36
Backward Gear 2	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$3\frac{3}{16}$	$\frac{9}{16}$	$\frac{5}{8}$	49	48	79	78	30	30	21	22
Backward Gear 3	$\frac{1}{2}$	$\frac{1}{4}$ full	$\frac{5}{16}$	$3\frac{7}{8}$	$\frac{7}{8}$	1	66	66	87	86	21	20	13	14
Backward Gear 4	$\frac{5}{8}$	$\frac{1}{4}$	$\frac{5}{16}$	$4\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{3}{8}$	76	75	91	90	15	15	9	10

The Cutting off, Exhaust, Expansion, and Compression, are given in per centages of the stroke of the piston.

The Front Stroke is from the buffer plank towards the firebox.

TABLE II.

Distribution of Steam by Straight Link Motion.

Stroke of Piston ... ... 24 inches.
Outside Lap ... ... 1 inch.
Inside Lap ... ... Line and line.
Steam Ports ... ... $1\frac{3}{8}$ inch × 12 inches.
Exhaust Port ... ... $2\frac{1}{2}$ inches × 12 inches.

Number of Notch.		Lead of Slide.		Travel of Slide.	Total Opening of Slide to Steam		Point of Cutting off.		Exhaust opens and Compression begins		Period of Expansion.		Period of Compression.	
		Front Stroke.	Back Stroke.		Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke	Back Stroke.	Front Stroke.	Back Stroke.	Front Stroke.	Back Stroke.
		Inches.	Inches.	Inches.	Inches.	Inches.	Per cent.	Per cent.	Per cent	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Forward Gear ...	7	$\frac{3}{16}$	$\frac{3}{16}$	$4\frac{1}{2}$	$1\frac{1}{8}$	$1\frac{1}{8}$	75	72	91	90	16	18	9	10
	6	$\frac{3}{16}$	$\frac{3}{16}$	4	$\frac{7}{8}$	$1\frac{1}{8}$	68	67	89	87	21	20	11	13
	5	$\frac{3}{16}$	$\frac{3}{16}$	$3\frac{3}{4}$	$\frac{3}{4}$	1	63	63	87	85	24	22	13	15
	4	$\frac{3}{16}$	$\frac{3}{16}$ bare	$3\frac{5}{16}$	$\frac{5}{8}$	$\frac{13}{16}$	55	56	84	81	29	25	16	19
	3	$\frac{3}{16}$	$\frac{3}{16}$ bare	$3\frac{1}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	44	46	80	77	36	31	20	23
	2	$\frac{3}{16}$	$\frac{1}{4}$ full	$2\frac{13}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	31	34	73	70	42	36	27	30
	1	$\frac{3}{16}$	$\frac{1}{4}$ full	$2\frac{11}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	21	23	65	61	44	38	35	29
Mid Gear..........	0	$\frac{3}{16}$	$\frac{1}{4}$	$2\frac{9}{16}$	$\frac{3}{16}$	$\frac{1}{4}$	10	10	50	46	40	40	50	54

The Cutting off, Exhaust, Expansion, and Compression, are given in per centages of the stroke of the piston.

The Lead is set equal in forward and backward full gear. The Front Stroke is from the buffer plank towards the firebox.

The Fore Eccentric Rod is coupled to the bottom of the link.

The construction of link preferred by the writer is shown in Figs. 13 to 16, the link being formed of a single rectangular bar, of about 2 ins. × $2\frac{3}{4}$ ins. section, having eyes at top and bottom to receive pins for connecting the eccentric rods. The block is made in the form of a rectangular frame, Fig. 16, surrounding the bar and sliding up and down it, and packed at the back by a lining strip to allow of wear. A more extended wearing surface is thus obtained by the single rectangular bar link, giving greater durability, and less expense in maintenance.

In place of the ordinary reversing lever and quadrant, the writer prefers to make use of a rack H, Figs. 1 and 2, on the end of the connecting rod I from the reversing shaft, gearing into a pinion on a vertical shaft, on the top of which is the hand wheel K. By this plan, the degree of expansion can be regulated with greater nicety, and greater power is obtained for reversing, so that the engineman may do his shunting without shutting off the steam. The rack is held securely in its position by a pinching screw, which is released by a treadle L acted upon by the foot; and a graduated scale or rim may be attached at the top of the shaft, in connection with the hand wheel.

Four engines are now working with the new motion, one of which has been at work for five months, during which time it has run 10,000 miles with very little wear of the motion; several other engines are also being fitted with the improved motion.

The Chairman regretted that Mr. Allan had been unexpectedly prevented from being present; he had sent two models showing the working of the new motion, one full-size and the other half-size.

Mr. Fernie had seen the new link motion at work at Perth, and thought it would prove very satisfactory in working and a decided improvement; the movement imparted to the valves was as true as in any motion he had seen, and the reversing was effected with greater ease than in any other motion that he was acquainted with.

Mr. Fenton had also seen the motion at work, and in his opinion it appeared to be the best application of the principle of the link that had yet been made. With the new motion, the boiler might be placed about 3 inches lower than with the ordinary link, and this was an advantage in many engines with large driving wheels, where the lowering of the boilers was limited by the clearance of the link motion. The ease of reversing was remarkable; the reversing lever might be held by the hand in any position whilst running with the steam on, owing to the several parts of the motion being completely in balance with one another.

The Chairman asked whether he had seen the single rectangular bar link that had been described.

Mr. Fenton replied that he had seen only the straight link with double bars; he did not know whether the single bar link was at work yet.

The Chairman proposed a vote of thanks to Mr. Allan for his communication, which was passed.

The Chairman said he had much pleasure in informing the Meeting that Mr. Allan had presented to the Institution one of the models of his link motion which had been exhibited. He hoped that others of the Members would follow the example, by presenting models to the Institution, so as to form a valuable collection for the use of the Members.

The Chairman announced that it had been proposed by the Council to hold an extra Meeting of the Institution in Glasgow, with the view of extending the sphere of usefulness of the Institution, by establishing periodical Meetings in Glasgow and other principal mechanical towns; and he hoped that every exertion would be made by the Members to procure papers for the occasion, and to be present themselves at the Meeting. He thought the progress of the Institution was very encouraging for the last year, and he fully anticipated that the present year would be the prelude to an important advance; he was confident of the result, if the Members did their best in promoting the interests of the Institution, by their personal attendance and communication of papers.

The Meeting then terminated.

Fig 14.
Fire box with closed bottom

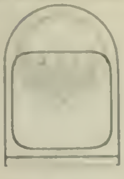


Fig 13.
Arrangement of Tubes
Old Plan

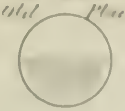


Fig 15.
Closed bottom Fire box with rounded top

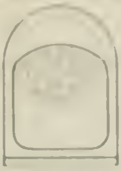


Fig 1.
Early Portable Engine with Outside Cylinder

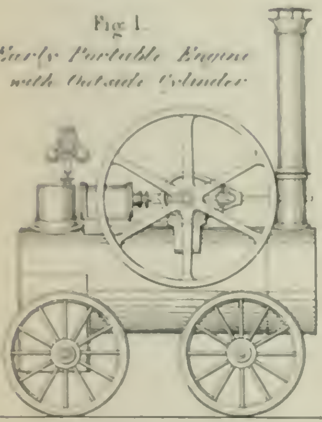
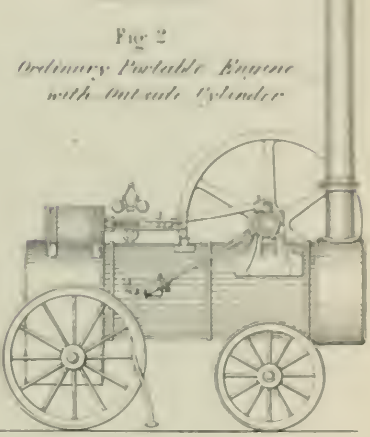


Fig 2.
Ordinary Portable Engine with Outside Cylinder



Portable Engine with Vertical Cylinder in house.

Portable Engine with Cylinder in Fire box

Fig 16.
Section of Engine house

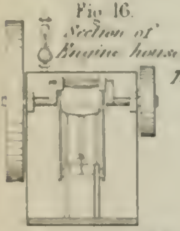


Fig 17.
Transverse Section of Boiler.

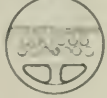


Fig 18.
Transverse Section of Boiler.

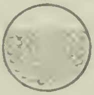


Fig. 3.
Longitudinal Section.

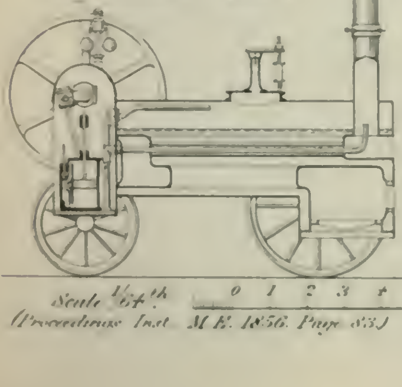
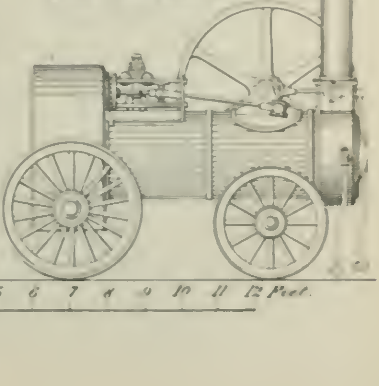


Fig. 4.
Side Elevation.



Scale $\frac{1}{64}$*th.* 0 1 2 3 4 5 6 7 8 9 10 11 12 *Feet.*

(Proceedings Inst. M. E. 1856. Page 83.)

AGRICULTURAL ENGINES.

Plate 39.

Portable Engine with Cylinder in Smoke box

Fig 5. *Side Elevation*

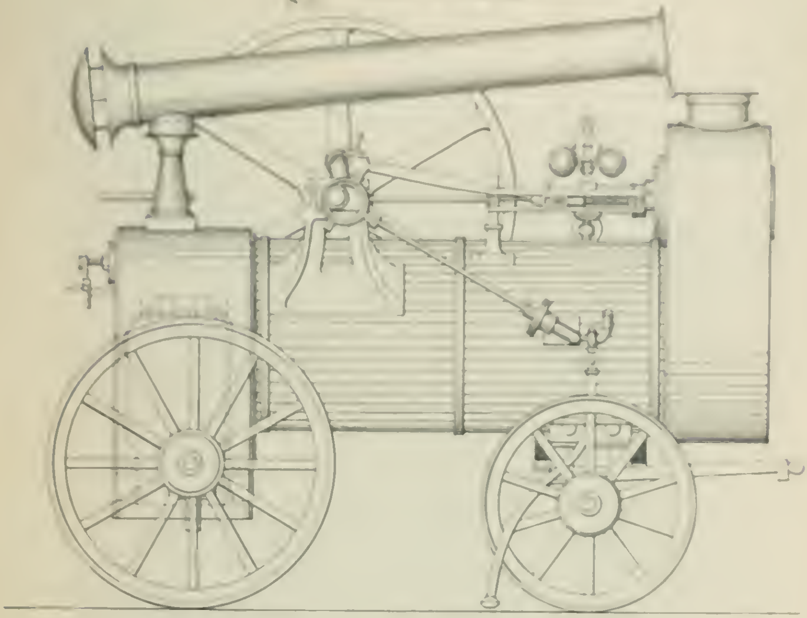


Fig: 6.
Back
Elevation.

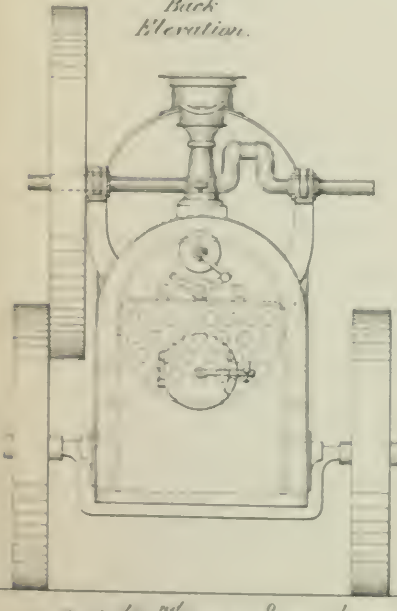
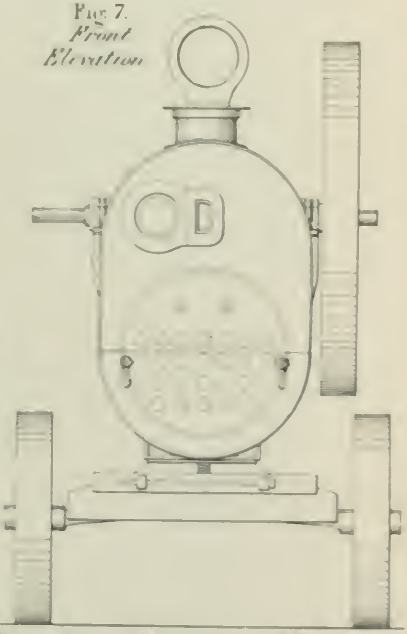


Fig: 7.
Front
Elevation.



Scale $\frac{1}{32}$*nd* 0 1 2 3 4 5 6 *Feet*

(Proceedings Inst. M. E. 1856. Page 85.)

AGRICULTURAL ENGINES

Plate 64

Fig 8.
Section of Cylinder and Steam Chest

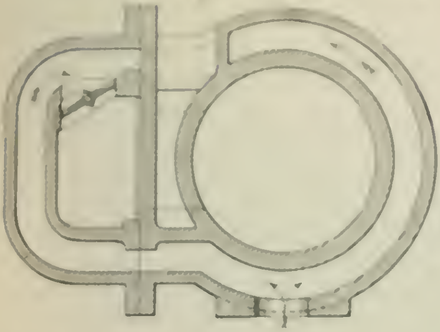


Fig 12
Governor

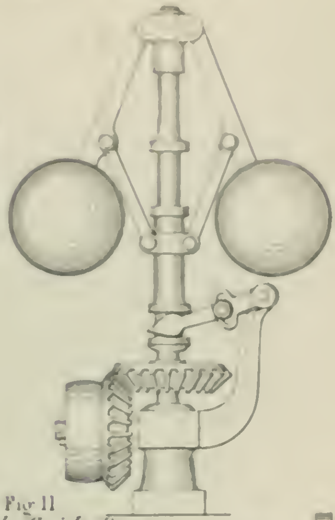


Fig 9. *Single Guide Bars*

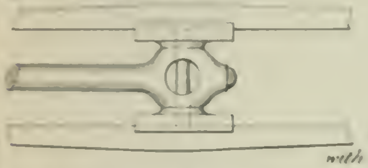
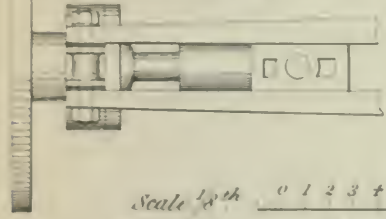
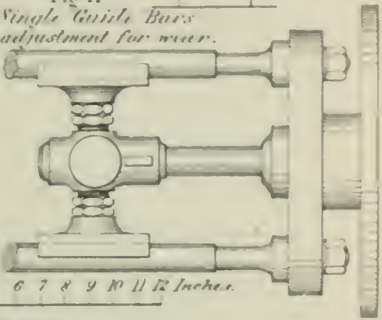


Fig 11
Single Guide Bars
with adjustment for wear.

Fig 10. *Double Guide Bars*





Scale $\frac{1}{8}$*th* 0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches.*

Dynamometer for testing Engines

Fig 19. *Side Elevation.*

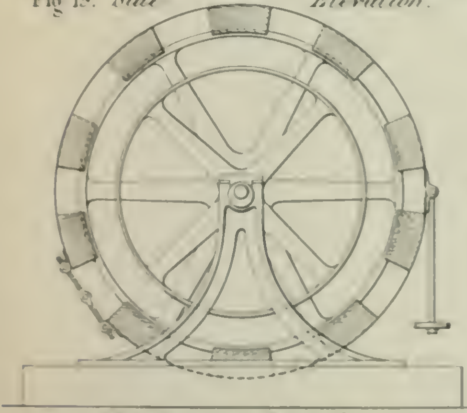
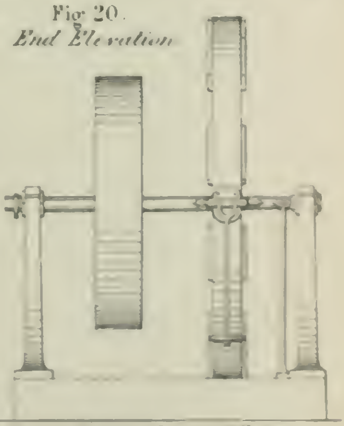


Fig 20.
End Elevation



Scale $\frac{1}{32}$*nd* 0 1 2 3 4 5 6 *Feet*

(Proceedings Inst M.E. 1856 Page 85.)

Indicator Diagrams taken from Portable Engines
while on the Dynamometer

Fig 21. *Cylinder 7 inches diameter. 8 H.P. weight*

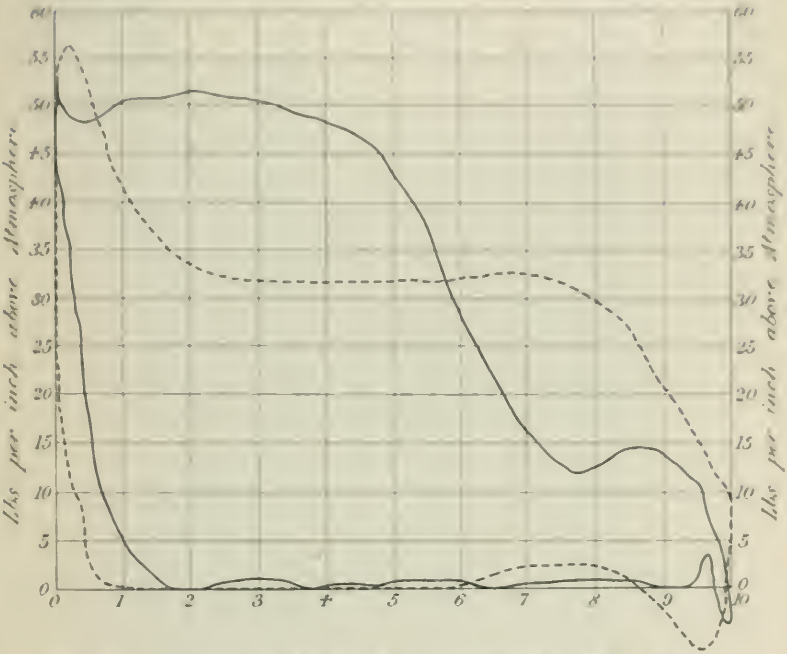
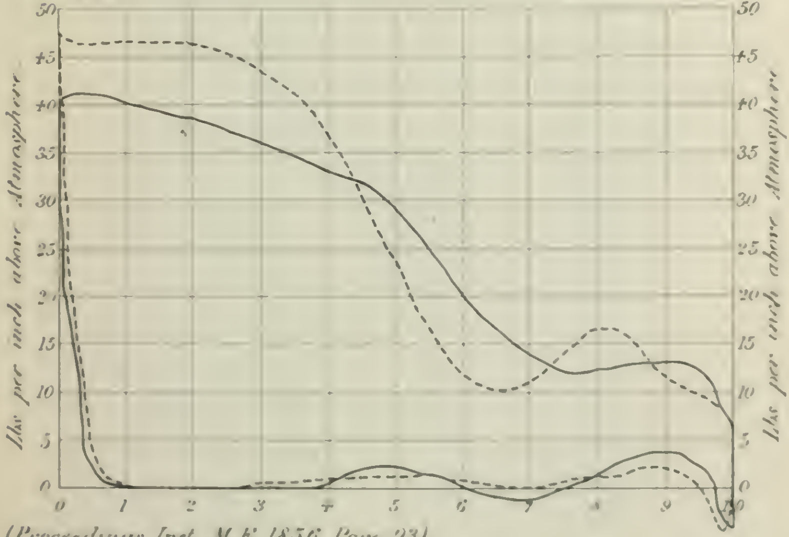


Fig. 22. *Cylinder 8½ inches diameter. 8 H.P. weight*

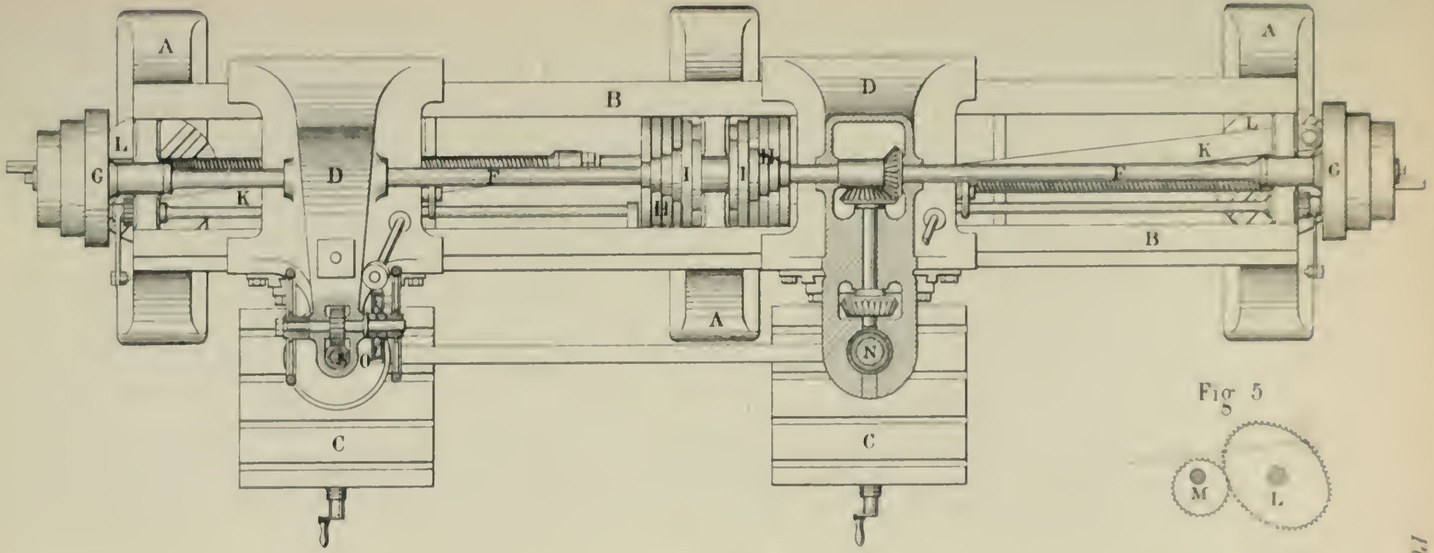


(Proceedings Inst. M.E. 1856 Page 93)

DRILLING MACHINE.

Fig: 1. *Plan.*

Fig 5



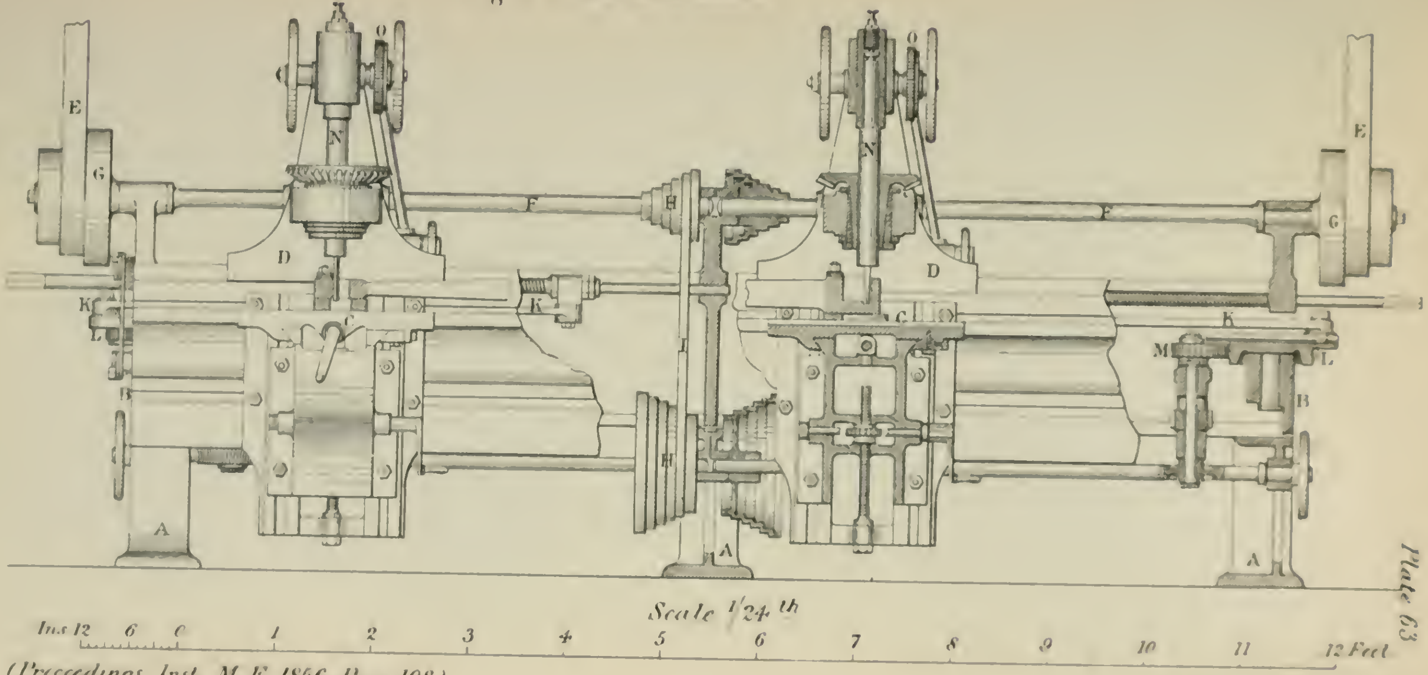
Scale 1/24th

Ins 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet

(Proceedings Inst. M. E. 1856. Page 108.)

DRILLING MACHINE

Fig. 2. *Front Elevation.*



(Proceedings Inst. M. E. 1856 Page 108.)

DRILLING MACHINE.

Fig: 3. *End Elevation.*

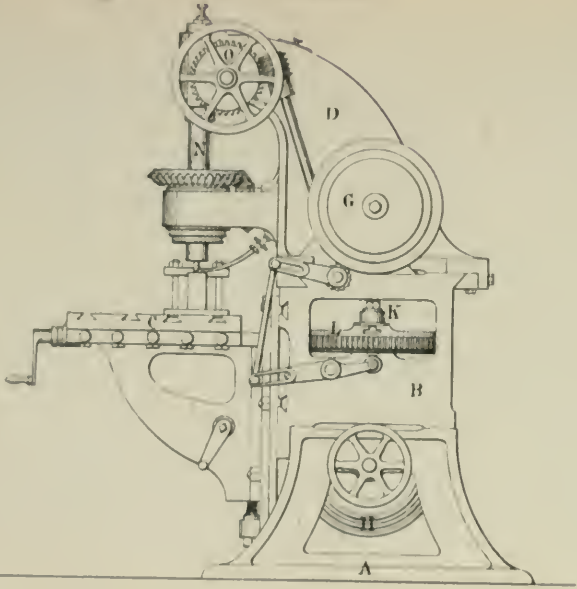
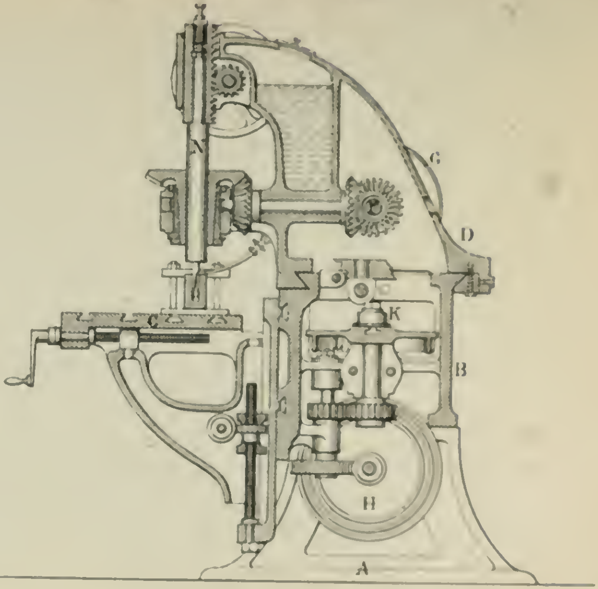


Fig: 4. *Transverse Section.*



Scale 1/24th

Ins 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet

(Proceedings Inst. M. E. 1856. Page 108.)

WATER METER.

Fig. 1. *Section of Meter and Filtering Chamber.*

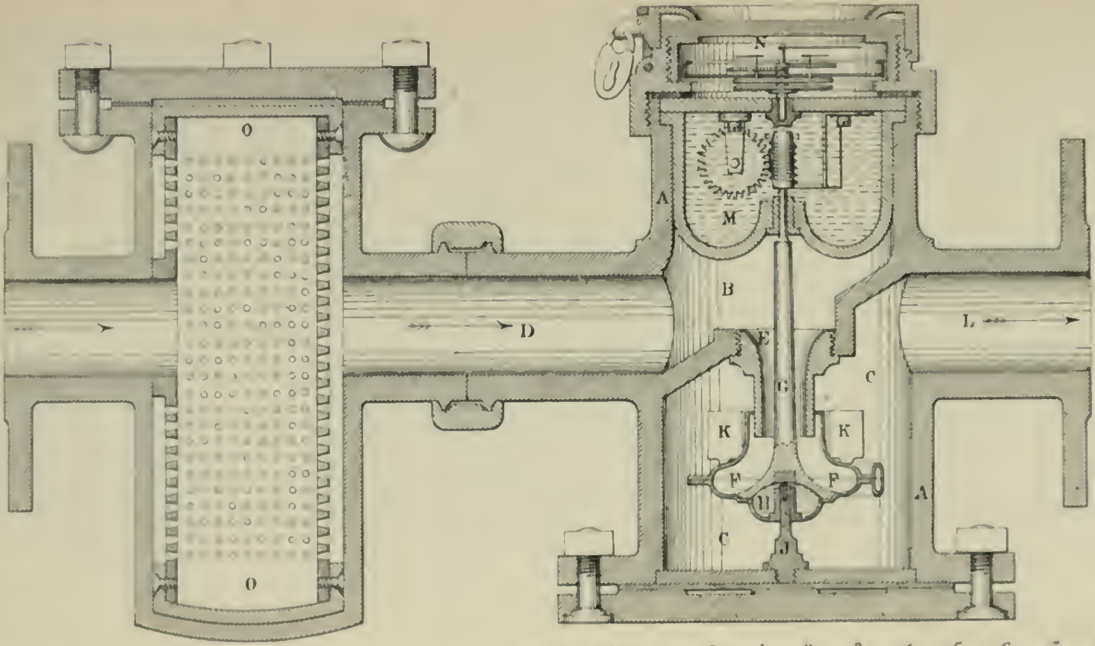


Fig. 2 *Perspective View of Drum.*

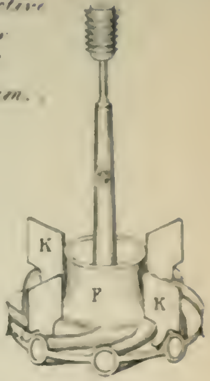
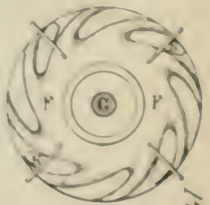


Fig. 3. *Plan of Drum.*



Scale 1/4th 0 1 2 3 4 5 6 7 8 9 10 11 12 *Inches*

(Proceedings Inst. M.E. 1856 Page 113.)

PROCEEDINGS.

July 30, 1856.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 30th July, 1856; Sampson Lloyd, Esq., in the Chair.

The Minutes of the last General Meeting were read by the Secretary, and were confirmed.

The Chairman announced that the Ballot Papers had been opened, and the following New Members were duly elected:—

MEMBERS.

James Allen,	Manchester.
William Anderson,	Dublin.
Edwin Bray,	Leeds.
Theophilus Wood Bunning,	Newcastle-on-Tyne.
Ambrose Edmund Butler,	Leeds.
John Dudgeon,	London.
William Dudgeon,	London.
James Eastwood,	Derby.
Joseph Freeman,	London.
Frederic Hayward,	Worcester.
Edward Jeffreys,	Shrewsbury.
Richard Laybourn,	Newport.
Alexander Grainger Linn,	Wisbech.
Charles Mitchell,	Newcastle-on-Tyne.
James Newall,	Bury.
John Shae Perring,	Bury.
John Pollard,	Leeds.
Frederick Rouse,	Leeds.

Louis S. Schmitthenner,	Birmingham.
Henry Wheetley Tyler, R. E.,	London.
John Waddington,	Leeds.
Thomas Waddington,	Leeds.
Edward Wilson,	Dublin.
Thomas Yarrow,	Arbroath.

HONORARY MEMBERS.

Henry E. Moss,	Liverpool.
Joseph Pettifor,	Derby.
William Singleton,	Leeds.

The following Paper, by Mr. William Waller, of Lincoln, was then read:—

ON THE APPLICATION OF STEAM POWER TO AGRICULTURAL PURPOSES.

The application of Steam Power to Agricultural Purposes, although of comparatively recent origin, and only within the last few years attaining a really practical character, has now become a subject of great importance, and is attracting much attention, both amongst mechanical engineers, in extending and designing new and improved applications, and amongst agriculturists, in availing themselves of the valuable and important aid that may be obtained from the new power. Rapid strides have been recently made and are now making in this direction, and the advantages and capabilities of steam power in many of the mechanical processes of agriculture have been remarkably developed by the active proceedings of the Royal Agricultural Society, and by the competition and stimulus to invention resulting from the annual exhibitions and prizes of the Society. These have led to so rapid an improvement, that the portable steam engine for agricultural purposes is now brought to a high state of perfection, and has reached such a high degree of efficiency and economy as to rival closely many of the best examples of the larger classes of engines, notwithstanding the difficulties attending the particular circumstances. The present importance of this class of engines may be illustrated by mentioning that from one manufactory alone, that of Messrs. Clayton, Shuttleworth, and Co., of Lincoln, with which the writer is connected, there have been turned out upwards of two thousand two hundred of these engines since 1845.

Agricultural steam engines proper are both portable and fixed; but those in use on "holdings," or belonging to tenant farmers, are generally portable; this may be accounted for in several ways.

The fixed engine would be attached to the freehold, and as erroneously supposed to become the property of the landlord under such circumstances, the tenant farmer would be sure to prefer the portable engine.

The portable engine saves the cost of fixing shafting to convey the power to the several processes carried on in the steading, being of itself readily moved from place to place, so that the power is applied direct to the various machines. Further, the cost of large barns is saved; for in many cases the corn is threshed and sacked in the field without stacking, and the corn is carried to the granary, while the straw is stacked; thus, in addition to the cost of barns saved, the expense of stacking and afterwards pulling the stacks to pieces for the purpose of threshing is also saved. On small farms the use of an engine is only temporary, and accordingly another great advantage attending the portable engine is that a farmer may hire his power, the engine being easily drawn from place to place; hence the very general introduction of steam power into agricultural pursuits. The concentration of the work into a general focus is not necessary with a portable engine, but for fixed engines it again becomes as necessary as in a factory.

The portable form of steam engine will probably still be found the most eligible, more particularly in reference to the further applications of steam power to cultivating the soil and reaping the crops, in which at the present time such rapid practical progress is being made.

From the application of the portable engine to matters foreign to agriculture much benefit has been derived; but it is proposed to limit the present paper to the consideration of the engine itself, and to reserve to a supplementary paper the application of steam to agriculture in its detail; the latter embracing the cost of steam as compared with horse or animal power, together with the greater certainty and expedition of the result, and also the probable ultimate use of steam in this direction, with the necessity that exists for such an extended use of it as shall put agriculture on the same footing as manufactures generally. It has been well observed that theoretically our modern agricultural practice is as much a manufacture as the spinning and weaving of cotton, or the smelting and puddling of iron. The farmer in his character of food producer has the same right to be termed a *manufacturer* of grain and meat, as the owner of the factory in his connection with the production of clothing from the raw textile materials which he works up.

There is some doubt as to who made the first portable engine. Mr. Dean, of Birmingham, made an engine in 1841, a description of which is given afterwards; and in the same year Messrs. Howden, of Boston, made one, which was exhibited at the Wrangle Show of the Lincolnshire Agricultural Society, in October, 1841. The latter was called a six horse engine, and had one cylinder, 8½ inches diameter, placed *vertically* on the boiler, which had two fire flues and one return flue; and the writer understands that it is still at work driving a scoop wheel in the Lincolnshire fens. With whom the idea originated he is unable to learn; but in 1839 the late Mr. Wingate, of Hareby, in company with Mr. Morton, the manager of Earl Ducie's Whitfield Experimental Farm, urged Messrs. Tuxford, of Boston, to design and bring out a portable steam threshing machine; whereupon plans were made and working models got out, but the subject was left in abeyance till 1842, when this firm produced a machine having the engine and threshing machine on one frame; the engine was placed "horizontally on the boiler with a rocking movement," being in fact an oscillating engine, and was called "the monkey on the bear's back." Nineteen of these steam threshing machines were made by this firm, after which the engine and machine became distinct, mounted on separate carriages. Messrs. Howden's was an engine only.

With the early attempts of other makers the writer is not acquainted, except with those of Messrs. Clayton, Shuttleworth, and Co., who turned out their first engine in September, 1845. It was an eight horse engine with two cylinders, 6 inches diameter, placed horizontally on the boiler; a wood frame ran along the sides and across the back, supporting a double-flued boiler; the crank shaft was fixed on the boiler by carriages on a metal frame, and a second shaft gearing into the crank shaft carried the flywheel, and was supported by high carriages from the wood frame; the guide bars were round rods, and the slide valves were worked by weighbars on the top of the cylinders.

This firm made the first portable engine with *one* cylinder placed horizontally on the firebox. The cylinder was cast with feet or lugs on it, and was carried raised above the firebox by wrought iron stilts or supports, and the crank shaft worked in high angular carriages; but in all other respects the engine was similar to the ordinary or outside cylinder engine of the present day. This engine, the pioneer of the present class of engines, and the first engine having only one cylinder (except that named before by Messrs. Howden, in which however the cylinder was placed vertically instead of horizontally), was made in October, 1848, and is now at work, the property of a friend of the writer's, in Norfolk.

Since 1841, when portable engines became a fact, there have been many changes in form, and some of the old patterns are still adhered to. A transition stage is shown in Fig. 1, Plate 58. The peculiarity of this engine is that the cylinder is fixed on a bedplate, which is bolted firmly to the boiler, and receives also the carriages of the crank shaft; between these an opening is left for the piston-rod guide, which consists of a bow on the end of the piston-rod, having another rod at the extreme end of the bow, working through a gland in the chimney, the bottom part of the bow resting on the barrel of the boiler. Inside the bow works the connecting rod, about 1 foot 7 inches long from centre to centre of eyes for a stroke of 10 inches. The engine with this piston-rod guide was made by Mr. A. Y. Barrett, of Horncastle, in 1848.

The more recent portable engines present many varieties of construction, and the author will proceed to point out several of the principal peculiarities. The performances of several of the portable engines while under trial by the judges of the Royal Agricultural Society are given afterwards, with a description of the dynamometer or testing machine, and a few points of essential practical difference are noticed.

In the portable engine by Messrs. Alchin and Son, of Northampton, the boiler is tubular, and a chamber is formed over the outside firebox shell to receive the cylinder. The exhaust steam is allowed to escape into this chamber, and is then conducted by a pipe to an external shell encircling the boiler barrel, whence it passes to the chimney. The engine is of simple construction; the piston-rod guide is formed of one round rod, fastened to the boiler at both ends, upon which slides a socket cast on the crosshead; the crank shaft works in carriages fixed on a casting attached to the boiler, and has a single overhung crank arm; the pump is worked from the crosshead, and the governor receives motion from a chain working over a **V** pulley on the crank shaft to another on the governor spindle.

Mr. Richard Bach, of Birmingham, has claimed to be the original maker of the portable engine in its present or perfected form, with the cylinder bolted on the outside firebox shell by feet cast upon it; the guide bars are fixed at one end to lugs on the cylinder cover, and at the other to a guide column or bracket attached to the boiler; the crank shaft works in carriages fixed on a saddle casting bolted to the boiler, and the boiler forms the frame of the engine. Prior to this engine, which was brought out by him for Messrs. Clayton, Shuttleworth, and Co., the few portable engines in use were very heavy in their consumption of fuel, and the gross weight of the machine was a contradiction of its portability. The engines now made by Mr. Bach are of the same description as above; but the writer understands that a modification in the application of the portable engine is in progress.

In Mr. Joseph Barrans' portable engine, made by Messrs. Hughes, of New Cross, the principal peculiarity is in the boiler, which is formed with a series of cup-shaped recesses over the entire heating surface of the firebox, with the object of economizing space and weight, and increasing the rapidity of steam generation.

In the engines made by Messrs. Barrett, Exall, and Andrewes, of Reading, the firebox, boiler, and smokebox, are all in the same horizontal line, and not raised one above the other as usual; the cylinder is bolted to a frame, the other end of which forms a carriage for the crank shaft. In an engine exhibited in the Great Exhibition of 1851, the governor was attached to a link, varying the grade of expansion, instead of cutting off the steam as in the usual plan; but the link and gearing connected with it were not applied to the commercial engines. A subsequent form of engine by these makers is not elegant in appearance, but its construction is supposed to be attended with some advantages; the boiler is enveloped in an iron casing, leaving an annular space all round, into which the heated air is turned after leaving the tubes, and passing along the whole of the outside of the boiler, envelopes the cylinder and is carried off by the chimney immediately above it; an expansion or back cut-off slide is provided, and the feed water is heated by the exhaust steam. In a third example, the peculiarities of both the other two are discarded; the firebox and boiler are in the same line at the top, and the cylinder is placed on the firebox; the boiler forms the frame of the engine, and the crank shaft is carried on brackets bolted to the boiler, the pump being brought near to the end of the shaft; the stop valve is in the steam chest, and is the old American or draw-out valve. The horizontal fixed engines by Messrs. Barrett are the same as their portable engines, only placed on a bedplate instead of being on the boiler. The vertical engines are neat firm examples, and have done good duty at the trials.

The commercial engines by Messrs. Clayton, Shuttleworth, and Co., of Lincoln, have been distinguished by their simplicity and efficiency, and the regularity of their government, the latter point having been specially noticed by the judges in the engines exhibited at the agricultural shows. In the old engines, the cylinder was unlagged, placed on the firebox, and a saddle bolted on the boiler supported the carriages for the crank shaft, which was a straight shaft with a crank arm on one end. This was superseded by lagged cylinders; then the saddle gave way to brackets; the crank arm was replaced by a double crank; and the present class of outside cylinder portable engines was introduced, having a compact arrangement, as shown in Fig. 2, Plate 58. The old butterfly valve has succumbed to the slide stop valve; and short passages for ports, a simple slide valve, and ample heating surfaces with good water spaces between the tubes, tend to make these engines good, durable, and economical.

For economy however the class of engine shown in Figs. 5, 6, and 7, Plate 59, is recommended. The first engine constructed on this plan by Messrs. Clayton carried off the first prize at the Gloucester Show in 1853. The cylinder is enveloped in a jacket, and is placed in the smokebox of the engine, which is carried up to receive it above the top of the boiler. The steam circulates in the jacket on its way to the cylinder, as shown in Fig. 8, Plate 60; and the outside of the jacket is exposed to a temperature of about 400° Fahr. As the pressure of steam in the boiler is not allowed to exceed 50 lbs. on the square inch, and as the equivalent temperature of steam at this pressure is about 300° Fahr., it is fair to assume that some heat will be communicated to the steam by the 100 degrees difference of temperature between the two sides of the plate of metal $\frac{1}{2}$ inch thick forming the jacket; and as it has been proved by successive experiments that this class of engine possesses a clear superiority over the outside cylinder engine, the most likely cause may be found in the super-heating of the steam in the manner described.

Two arrangements for guide bars are shown in Figs. 9 and 10, Plate 60. That shown in Fig. 9 is for two single guide bars and a forked connecting rod; a boss is forged on the end of the piston rod and is bored out to receive the gudgeon, and a cross pin to hold this in place forms a connection also to the brass guide blocks. In case of wear the brasses are packed up off the piston rod end by means of thin washers, slipped over the cross pin, and inserted between the iron and brass. When it was wished to draw the piston out, it was necessary to take the piston plates off the rod, and as this was a serious objection, the above plan was succeeded by the other, shown in Fig. 10, where four guide bars are used. The packing inserted between the guide bars and the bearers or lugs, on which they are fixed at the ends, is composed of washers, which are withdrawn as the blocks wear, thus keeping the piston rod in the line of the centre of the crank shaft. The crank shaft is seen in Fig. 6, Plate 59, and is formed of a bar of round iron, jumped and bent in moulds, thereby retaining the pile or grain of the iron in the direction of the pull on the crank. The governor, shown in Fig. 12, Plate 60, is simple and efficient, the lift of the slide being communicated directly to the throttle valve spindle, without the use of rods or links, by means of a slotted arm which is used to alter the speed a little when required; the governor is driven by a flat leather belt from the crank shaft, instead of by V pulleys with gut or chain, which are found to slip in working. The arrangement of tubes, shown dotted in Fig. 6, Plate 59, is new, and is the one generally adopted; the spaces between the tubes are made gradually to increase from the top to the bottom, for the purpose of allowing greater space for the deposit from the water. For places where the water is bad or salt the tubes are spaced out wider apart, as shown dotted in Fig. 7.

The portable engines by Messrs. Clayton have passed through several stages, and one which was designed for the Great Exhibition in 1851 had a vertical boiler in a carriage, with a vertical oscillating engine fixed in the carriage. The horizontal fixed engine is made according to two arrangements; in the first the engine is raised above the bedplate, and has a plain shaft with a crank arm, the guide bars are single, and the pump is worked from the crosshead; the second arrangement is with a planed bedplate, having double guide bars and the improved governor, and the pump is worked from an eccentric on the driving shaft. In the portable engines the steam and exhaust pipes are kept out of sight by being placed in the boiler, and in the fixed engines they are kept in the bedplate as much as possible.

Mr. Alexander Dean, of Birmingham, has been noticed previously as being the first who made the portable engine, or, more correctly, the first who made the engine portable. His first engine was a single vertical fixed engine on a metal frame, with a vertical boiler and wheels attached to the plate or frame, and double engines were also made of the same kind; the crank shaft was carried on a frame supported above the cylinders by columns; there was a bow on the end of the piston rod, with a spindle from the end of the bow to a guide working in the frame, and the connecting rods worked in these bows down again on to the cranks. As this engine was meant to supersede horse gear, the plan usually employed for conveying the power from horse gear to the machine by means of rods and universal joints was here also adopted. The present make by Mr. Dean is that of the locomotive boiler with a horizontal cylinder.

The engines by Messrs. Garrett and Son, of Saxmundham, are made with Horton and Kendrick's firebox, which they consider to be more economical in consumption of fuel, stronger, and less liable to wear and tear than any other, and thus more suitable for subjection to the influence of bad water. By introducing vertical or oblique corrugations into the inner shell of the firebox, a larger surface is exposed to the action of the heat. The smokebox is carried down to form a tank, to the bottom plate of which is fastened the turnplate for the small wheels. The cylinder is provided with a steam jacket and is placed on the firebox.

In the engine of Messrs. Hornsby and Son, of Grantham, shown in Fig. 4, Plate 58, the cylinder is let into the steam chamber over the firebox, the outside box being carried up to receive it. The earlier engines were made with a return crank shaft, but lately the plan has been altered to the old method of having a crank arm on a straight shaft, and the boiler is now made indented to allow the crank and connecting rod end to clear. Among the chief points worthy of notice, besides the position of the cylinder, may be mentioned the manner of adjusting the wear of the guide blocks, which is effected by means of lock nuts acting upon a screw, the blocks or slide pieces resting on these nuts, as shown in Fig. 11, Plate 60; the tubes also are arranged in a peculiar manner, being set in a semicircle, following the curve of the boiler, as shown in Fig. 18, Plate 58. The pump is attached to the base of the chimney, and a heating apparatus for the feed water is placed in the smokebox. The engines have proved good and economical, but what saving can be effected by placing the cylinder in the steam chamber alone is a matter of doubt with the writer, excepting only that effected by preventing condensation.

The number of prizes carried off by Messrs. Hornsby may perhaps be attributed to the number of tubes in their engines, and also to the enterprising spirit they have shown; they are unwearying in their exertions to obtain the highest possible duty out of the portable engine, and the writer understands that, in order to determine the best size of cylinder for a certain power, they have had one cast of great thickness, and tried it at various diameters, with of course one fixed length of stroke, boring it out after each series of experiments, and thus arriving at a positive result. The high duty which they have obtained at Paris during the late show in June, 1856, working for three hours on a dynamometer with 3½ lbs. of coal per horse power per hour, is remarkable; in this experiment they competed successfully with the English prize engine of 1855, by Messrs. Tuxford, and considerably exceeded any duty previously obtained by themselves.

The engines of Messrs. Ransomes and Sims, of Ipswich, have for many years stood well in the trials of the Royal Agricultural Society. The writer believes that these are the only portable engines which have the centre of the engine in the centre line of the boiler. The connecting rod is shorter than that of the other makers of the present day, being only about twice the length of the stroke. The turnplate of the engine is spherical, so as to yield to any obstruction or unevenness of the road, and the "locking gear" is made convex on the underside, so as to allow the axle, which is made concave, to fit; the engine is thus always borne upon the same three points, in whatever position it may be placed, and the axle is free to move vertically at either end. The 7 inch cylinder has a stroke of 11 inches, and the engine makes 150 revolutions per minute. Messrs.

Ransomes have also for the last two years taken the prize for the best fixed engine, tested in the same way as the portable engine, and worked by the boiler of the Royal Agricultural Society.

The engine by Messrs Robey, Scott, and Co., of Lincoln, shown for the first time at the recent Society's meeting at Chelmsford, possesses some new features. The firebox has a water space all round and underneath, as in Figs. 14 and 15, Plate 58, except where a door is placed to get the ashes out; the object of this is to carry the sediment from the side water spaces into the space immediately below the fire, and thus save the firebox plates. The firebox is rounded over above the firedoor, as in Fig. 15, and slightly so at the sides, thus giving a freer circulation for the water. The arrangements of tubes are given in Figs. 14 and 15, and an advantage aimed at in the former plan is that a rod can be passed down between the rows of tubes to stir up the sediment in the boiler.

An engine by Messrs. Simpson and Barnes, of Manchester, was also exhibited at Chelmsford, having been entered by Mr. Chamberlain to work his brick machinery. The engine is somewhat similar in construction to those already described, the peculiarity being in the boiler, which has a longitudinal flue containing the firebars with a bridge at the back; a smokebox or chamber is formed at the end, of the same size as the shell of the boiler, from which tubes are carried to a second chamber over the firebox, above which is the chimney. The objects aimed at in this construction are to gain as much heating surface as in a firebox boiler at less expense in making, and also to make use of all the gases evolved from the fuel, by the increased length to be traversed before the tubes are reached.

Messrs. Tuxford and Sons, of Boston, have been referred to before as being early in the field with the portable engine, and the general make of their engine is shown in Fig. 3, Plate 58. The engine is "housed," or placed in a chamber at one end of the boiler, and is either vertical or vertical oscillating; that shown in Fig. 3 is vertical and fixed in the house; the crank is wide in the jaw to receive two connecting rods, one of which works at each side of the cylinder, as shown in Fig. 16, Plate 58. The engine is compact, and a creditable piece of machinery, but somewhat difficult for hands inexperienced in that make of engine to get at so as properly to execute repairs. The objection to the "housing" of the engine is the heat of the chamber, which acts as an "anti-lubricator." The boiler is novel in design, being a combination of flue and tubes, a transverse section of which is shown in Fig. 17, Plate 58. Messrs. Tuxford carried off the first prize at the Carlisle Show, beating Messrs. Clayton's engine by about twenty minutes, and the next by more than thirty, and obtaining a result with the eight horse power portable engine of a little less than $3\frac{3}{4}$ lbs. of coal per horse power per hour.

The engines above described are those of makers most extensively engaged in the manufacture of agricultural steam engines, or whose engines offer any marked peculiarity; but another plan may be noticed that is applicable to them all, which, though not strictly intended for agricultural purposes, possesses a recommendation in the great safety from fire. This plan, brought out by Messrs. Alexander Chaplin and Co., of Glasgow, and termed by them "forced combustion," consists in contracting the chimney and forming a seat for a valve, which is raised or lowered from the outside by a chain or rod and a lever. The valve may be made of fireclay or other material, and is perforated with small holes sufficient to keep up the necessary combustion, all the heat being kept in the boiler. It is not stated however whether any saving accrues from the adoption of this plan. The action of the flame upon the plates in the boilers of Messrs. Simpson and Barnes, and Messrs. Tuxford, is somewhat the same, the heat being kept back in the flue of large sectional area, in consequence of the smaller area of the tubes. A simpler plan, by which the draught would not be checked, would be to carry the chimney down into the smokebox, instead of allowing it merely to rest on the top plate; by this means the carbonic acid gas, the product of perfect combustion, would from its greater specific gravity be carried off first, leaving the hot partially burnt gases at the top of the box; whereas the hotter gases are now carried off first, leaving the denser portion to choke the draught through the lower tubes. This plan is more particularly to be recommended from the fact that the denser portion is not nearly so hot as the gases evolved unconsumed or unchilled during combustion by coming in contact with the tubes or tube plate. The plan of "forced combustion" might be carried out partially by merely contracting the bottom of the chimney.

The manner in which the engines are tested by the judges of the Royal Agricultural Society is as follows:—

The various engines are entered, declared at a certain power at which only they are to be tested; thus, suppose an engine having a 5 ft. flywheel pulley entered as an eight horse power engine, running at 120 revolutions per minute. Eight stone of coal, of 14 lbs. to the stone, with a certain quantity of wood to light the fire, are given to the engineman, who has previously had the engine at work, and run the steam down to 20 lbs. or 25 lbs. per square inch pressure, as the case may be, and emptied and swept out the firebox. The fire is then relighted, and the steam is got up to 48 lbs. per square inch, at which pressure the engine must start. The dynamometer, shown in Figs. 19 and 20, Plate 60, is supposed to have a 3 ft. 6 ins. belt pulley, and a 4 ft. 6 ins. wheel with a friction break on it; then the centre of the pin or pointer to which the scale is attached being 2 ft. 7½ ins. from the centre, equivalent to a circumference of 16·5 ft., it will require a weight of 93·33 lbs. suspended from the pin to give the desired 8 horse power, according to the following expression:—

$$\frac{93{\cdot}33 \text{ lbs.} \times 16{\cdot}5 \text{ ft. circumf.} \times 5 \text{ ft. pulley on engine} \times 120 \text{ revs. per min.}}{3{\cdot}5 \text{ ft. pulley on dynamometer}} = 264{,}000 \text{ lbs. raised 1 ft. high per minute.}$$

$$\text{And } \frac{264{,}000}{33{,}000} = 8 \text{ HP} = \text{the horse power of the work done.}$$

The engine being started with a belt connecting the flywheel to the belt pulley, a man is placed at the adjusting screw of the dynamometer to slacken or tighten the friction blocks, so as to keep the weight exactly in balance with the friction, and the pointer in a line with the centre of the shaft, during the whole time of working the engine. The number of revolutions of the break wheel is registered on a counter by means of an eccentric on the shaft of the dynamometer, shown in the side elevation, Fig. 19. It is the business of the engineman to get the greatest possible number of revolutions out of the engine; then the total number of revolutions of the break wheel divided by $\frac{5 \times 120}{3{\cdot}5}$ gives the number of *minutes of duty* the engine has done, that is, the number of minutes of time the engine would have taken, if it had made *exactly* 120 revolutions per minute during the entire time of running, $\frac{5 \times 120}{3{\cdot}5}$ being the number of revolutions per minute of the break wheel, corresponding to 120 revolutions per minute of the engine. The minutes of duty converted into hours and decimals, and divided into the 14 lbs. of coal supplied per horse power, give the duty performed in the quantity of coal consumed per horse power per hour. Thus at the Carlisle Exhibition, Messrs. Tuxford's engine did duty 3 hrs. 47½ mins., or 3·8 hrs.; this with 14 lbs. of coal per horse power gives 3·7 lbs. of coal per horse power per hour.

The following Table I. gives the weight in pounds, to be placed in the scale of the dynamometer shown in Figs. 19 and 20, for each horse power from 4 to 10 horse power, at intervals of 10 revolutions from 110 to 150 revolutions per minute of the engine. The Table is calculated by the following formula:—

$$w = \frac{HP \times 33000 \times d}{c \times D \times n}$$

where w = the weight in lbs. to be placed in the scale of the dynamometer, HP = the horse power of the engine, d = the diameter in feet of the pulley on the dynamometer, c = the circumference in feet corresponding to the distance of the pointer carrying the weight from the centre of the break wheel, D = the diameter in feet of the driving pulley of the engine, and n = the number of revolutions of the engine per minute.

TABLE I.

Weights for Dynamometer.

Revolutions of engine per minute.	4 Horse Power.	5 Horse Power.	6 Horse Power.	7 Horse Power.	8 Horse Power.	9 Horse Power.	10 Horse Power.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
110	50·90	63·64	76·36	89·09	101·80	114·55	127·28
120	46·66	58·33	70·00	81·67	93·33	105·00	116·66
130	43·08	53·85	64·61	75·39	86·16	96·92	107·70
140	40·00	50·00	60·00	70·00	80·00	90·00	100·00
150	37·33	46·67	56·00	65·33	74·66	84·00	93·34

The following Table II. gives the performance of the first and second prize engines at the meetings of the Royal Agricultural Society for six years, 1849, 1850, 1852, 1853, 1854, and 1855, and the two highest at the Paris Exhibition of 1856, showing a progressive increase in the duty obtained.

TABLE II.

Duty performed by Portable Agricultural Engines.

Year.	Place at which Show was held.	Duty performed. Coal burnt per horse power per hour while doing the work. First prize.	Second prize.
		lbs.	lbs.
1849	Norwich	11·50	10·78
1850	Exeter	7·56	7·77
1852	Lewes	4·66	5·45
1853	Gloucester	4·32	4·82
1854	Lincoln	4·55	5·10
1855	Carlisle	3·70	4·05
1856	Paris	3·50	4·00

It will be remarked that the duty performed in 1853 is higher than that in 1854; this arose from the fact that, exclusive of the 14 lbs. of coal per horse power weighed out to the enginemen to get up steam and run the engines, they were allowed to fill the firebox in addition; but in 1854 this practice was stopped, and the fireboxes were swept out to prevent any advantage in this respect. It will thus be seen that the duty represented prior to 1854 is more or less fictitious.

Table III. (appended) gives the general results of the trials of the portable agricultural engines at the shows of the Royal Agricultural Society for the six years previously named.

Table IV. (appended) gives the principal dimensions of the portable engines exhibited at the shows of the Royal Agricultural Society, at Lincoln in 1854, and at Carlisle in 1855, by the makers included in Table III.

Indicator diagrams taken from four of the recent portable engines are given in Figs. 21 and 22, Plate 61; in each case the engine was working with an 8 horse power weight in the scale of the dynamometer. In Fig. 21, the full line is taken from an engine with a cylinder 7 inches diameter, and having $1\frac{1}{4}$ inch lap of the valve, making 115 revolutions per minute; and the dotted line is from an engine with a cylinder 7 inches diameter, and having $\frac{3}{4}$ inch lap of the valve, making 150 revolutions per minute, the duty being 4·40 lbs. of coal per horse power per hour. In Fig. 22, both the full and dotted lines are taken from engines having a cylinder $8\frac{1}{2}$ inches diameter, and $\frac{3}{4}$ inch lap of the valve, with an additional back cut-off valve, making 115 revolutions per minute; the engine from which the dotted line is taken performed a duty of 4·05 lbs. of coal per horse power per hour.

In the several engines that have been described above, some points of essential practical difference have been alluded to in passing, which demand a more special consideration; and of these the cylinder, as one of the most important, may be noticed first.

The cylinder is in some cases exposed on the top of the firebox unlagged, and in others it is placed in the same position, but is covered sometimes with lagging and sometimes with a steam jacket also. A cylinder felted and lagged will of course be more economical than one exposed to the atmosphere, by rendering available the steam otherwise lost in condensation. Then we have the cylinder placed in a chamber in the smokebox, over the firebox or at the opposite end to the firebox, with the exhaust steam turned into the chamber. Again, the cylinder is placed in the steam chamber over the firebox, increasing the size of the steam chamber and consequently the area of the plates exposed to the atmosphere. In other engines the exhaust steam is thrown into a jacket round the cylinder; while in others a steam jacket is provided round the cylinder, thus increasing the surface for condensation.

A further improvement gives the advantage of the steam jacket exposed to gases at a higher temperature than the steam, so as to prevent any loss by condensation, and to gain if possible by superheating the steam on its passage to the cylinder. That there is a possibility of a gain may be gathered from the fact that steam at a pressure of 100 lbs. per square inch has a temperature of 342° Fahr.; and at a pressure of 50 lbs. per square inch a temperature of 300° Fahr.; or in round numbers one degree gained in the temperature is one pound gained in the pressure on the piston, while the indicator on the boiler remains unchanged.

In all the above arrangements, and in most engines of modern make, the cylinder is placed horizontally; and although there can be no doubt as to the superior durability of a vertical cylinder, the latter is not at all times the most convenient arrangement. In one make of engines that has been described the cylinder is placed vertically, and the engine is housed to protect it from dirt and grit; in this respect the plan is an improvement, but the heat of the house or chamber is too great to admit of economy of oil or tallow, and the position of the cylinder below the water line of the boiler is certainly conducive to priming, by converting the steam pipe into a syphon.

The slide bars or guides are made either single or double, but whether two or four bars are most economical is still open to discussion; and the difficulty of getting four slide bars adjusted may be weighed against the uneven wear of the double-ended or forked connecting rod. The three modes of adjusting the bars or blocks to the wear are noticed above and shown in Figs. 9, 10, and 11, Plate 60. Another plan has been proposed, having one guide only fixed on the boiler independent of the cylinder, and therefore liable to be acted upon by the expansion of the boiler. These are matters of detail, and the last plan has no doubt the advantage of easy construction, although a very slight derangement would have the effect of throwing the connecting rod atwist.

The length of the connecting rod most economical in practice in proportion to the length of stroke of the engine requires some notice. The old engine, shown in Fig. 1, Plate 58, has a connecting rod 1 foot 7 inches long from centre to centre of eyes for a stroke of 10 inches; more modern engines have a rod about 2 feet long for a stroke of 11 inches, or sometimes 10 inches, as in an engine exhibited at Lincoln, while some have a rod as much as 4 or 4¼ times the length of the stroke.

The crank shafts of some engines are made of a straight bar with collars on it, having a crank arm keyed on at the end, and of course can give off their power only from one end; while others for greater convenience have been made with double or return cranks with square jaws; but as the latter are forged solid and then slotted out, the pile or grain of the iron is necessarily cut in two. A simpler, and in the writer's opinion a stronger shaft is that shown in Fig. 6, Plate 59, formed of a bent bar, jumped where it is to be bent, and brought into shape in a mould, the pile of the iron being thus kept in the direction of the strain exerted in the pull. It is worthy of remark that in the shafts of portable engines allowance is generally made for the expansion of the boiler, by putting collars on the shaft at the journal nearest the crank only, two collars being made to the one journal, and leaving the plain shaft to pass through the other bearing, so as to yield to the expansion, the cylinder going with the crank and the bearing at that end of the shaft.

In the governor of an engine the complaint is generally that when most required it is of least use. In the more recent engines the pendulums are shorter and the weights increased in size, and leather driving bands are used, being found most advantageous. The throttle valve should be close to the steam chest in order to govern the engine properly, as there will then be but a small quantity of steam past the valve. A more compact arrangement or one more delicate in working cannot be found than that already described and shown in Fig. 12, Plate 60.

The general plan of boiler for the portable engine has tubes connecting the firebox and smokebox, on the plan of the locomotive engine; the firebox has water spaces round, and the crown is stayed with cross supports, the sides also being held to the plates of the outside box by screwed stays rivetted over, or with nuts on one or both ends.

The arrangement of tubes varies with different makers, the old and common plan being shown in Fig. 13, Plate 58. The arrangements shown in Figs. 6 and 7, Plate 59, with irregular spaces, increasing as they approach the bottom of the boiler, have been found after eighteen months' trial to answer exceedingly well, and the writer believes that neither of these plans has been brought under special notice. Other arrangements, except that shown in Fig. 18, Plate 58, are in use in locomotive and marine boilers. Much doubt is still expressed as to the best way to arrange tubes for economy of working and durability of the tube plate. The plan shown in Fig. 14 is identical with the old plan shown in Fig. 13, except that the rows of tubes run vertically instead of horizontally.

An important feature in a boiler is the shape of the crown of the firebox. If the water in circulation is considered to take the form of a curve from either side of the box on leaving the plates, it would naturally result that the nearer this shape is followed the better effect will be produced; but if the water leaves the plates abruptly and rises nearly perpendicularly, the straight side may be continued. The writer believes that a firebox rounded on all sides except the tube plate would allow of better circulation and consequently make more steam than one with straight sides. Experiments have proved that flame will pass over a plain flat plate without imparting so much heat as when a number of studs or projections impede the progress of the flame and conduct the heat into the water; this should show the fallacy of attempting to obtain a high duty with very smooth firebox surfaces. Projecting stays, and plates bent in an easy curve to the tubes, so as to allow a free passage for the flame, seem to be the desideratum. The only fireboxes with rounded plates that have fallen under the notice of the writer in portable engines are that shown in Fig. 15, Plate 58, and that in the Carlisle prize engine. The ashpan firebox, or closed bottom firebox, shown in Figs. 14 and 15, is said to cause an important saving of fuel over the ordinary plan, but further experiments are necessary to prove the exact saving effected. In the boiler shown in Fig. 17, the firebox has a semicircular flue with a flat top running along the boiler, the top being stayed to the bottom of the flue by a midfeather of some length. A small chamber next the engine-house receives the end of the flue, as well as the tubes, which convey the smoke and gases to a second chamber at the firebox end, whence the chimney passes up through the steam room of the boiler, carrying the smoke away.

Before quitting the subject of the boiler, it will be well to state that in those racing engines by which the highest duty has been performed in 1854 and 1855, there has been the smallest quantity of water. The tubes are set out with the smallest possible water spaces, and the barrel of the boiler is nearly filled with them; the area of the firegrate is reduced to a minimum, the coal used being Welsh and requiring less air for combustion than any other. The following extracts from the report of the judge of the North Lincolnshire Agricultural Show at Boston last year will give a few particulars of the two engines tried there, the other being far behind.

"Messrs. Tuxford's engine, eight horse power nominal; time in getting up steam, 2 hours 5 minutes; coal burnt in getting up steam, 29·28 lbs.; coal burnt per horse power per hour, 4·59 lbs. Messrs. Tuxford's engine worked out the best duty, giving a saving of 44 lbs. of coal per day of 10 hours"; but it is added that the length of time in getting up steam more than counterbalanced this saving. "This engine contained 89 tubes in the boiler, of 2 inches diameter, but furnished with ferrules at the firebox end, reducing their internal diameter to $1\frac{1}{8}$ inch."

"Messrs. Hornsby's engine, eight horse power nominal; time in getting up steam, 53·5 minutes; coal burnt in getting up steam, 32·17 lbs.; coal burnt per horse power per hour, 5·14 lbs. Messrs. Hornsby's boiler was furnished with 61 tubes, tapering from $2\frac{3}{8}$ inches diameter in the smokebox to 2 inches diameter in the firebox."

The coal used was common Yorkshire coal, such as is generally used for this class of engine.

The benefit of the prizes given by the Royal Agricultural Society for the last few years has been doubtful; firms have been at great expense to construct *one* engine which should perform the highest possible duty for the sake of getting the prize, and every effort has been concentrated on this one object, but no alteration has been made in the general or commercial engines. The farmers, whom these trials were meant to benefit, are no gainers by them; the racing engines would be unsafe in their hands without an experienced engineman, owing to the contracted water spaces; and although the trials may tend to develop the results of careful experiment and mechanical skill, and may be of interest to the mechanical world, yet they are not of any use to the agriculturist, unless those engines tried at the shows are required to be on the same plan and similar in every respect to the commercial engine of the same firm. The trials of the Royal Agricultural Society of England are to be only triennial, and before 1858 we may expect to find a much higher duty than we can even now boast of; but the fairest way would be to try the commercial engines built by the several firms, and allow no difference to be made unless in finish and painting. The real working capabilities would then be tested, and farmers and the public generally would have some criterion to go by, and the trials would prove a boon. Such is now the case with mills, threshing machines, and other implements, and why engines should be excepted from the general rule it is difficult to say.

The variety of purposes to which the portable engine is applicable is very great, and its use is being now rapidly extended.

The portable engine is particularly qualified for winding light weights, such as bricks and mortar for building purposes, by means of a second shaft fixed on the boiler. By being placed on a carriage it has also been used to work one or more crabs for pile driving. The portable engine was pressed into the service of our country to draw stores from Balaklava to Kadikoi in the Crimea, until the locomotives were sent out; it worked the rope which supplied ammunition to the front, pumped water for the troops, and was placed on the deck of a vessel in the harbour to unload vessels arriving with stores; it proved useful in war, and in peace its usefulness is continually increasing; shod with an endless railway and made locomotive, it was then used to draw the guns and heavy ammunition where the feet of horses failed, and now similarly harnessed is employed to plough and harrow the ground.

The portable engine is yet only in its infancy, but has been brought on fast in its sphere of usefulness. Among the most important recent applications to agricultural purposes are, Willis's Farmer's Locomotive Portable Engine, Boydell's Traction Engine, Usher's Steam Plough, the various cultivators that have been brought forward to till the soil, and the several plans that have been employed for threshing, dressing, and grinding, &c. The transition from the use of animal power applied direct by treading or dragging some instrument over the full ears of corn, to the substitution of machinery, forms an important and interesting subject, with the advances from the various "horse gears," as they are technically called, to the gradual use of steam, the introduction of which was effected against prejudice aided in many cases by the insurance offices, some of which refused altogether to insure the property where portable engines were allowed to work, and others accepted it only at a very high rate.

In regard to the application of steam power to the tillage of the ground, it is necessary to consider the manner in which this is practicable. In some instances it has been attempted to make the engine turn a set of knives or breasts similarly shaped to those known as "shieldboards" or "mouldboards" in ploughs, placed on a revolving drum driven by the engine; in others it has been proposed to use plain knives to cut at a fixed or variable depth below the drum or roller to which they are attached. Some have tried to give a straight vertical motion to a spade or set of digging instruments, causing it to enter the ground a certain depth, and then an end motion by which the earth is thrown behind or merely turned over. Another plan put in practice has been to make the portable engine locomotive, dragging a frame of ploughs and harrows behind it; this is one of the plans now competing for the prize of £300 offered by the Royal Agricultural Society.

The vital point in the application of steam in the place of animal power consists in the following essential distinction:—the horse to give out his power effectively must move at a slow speed and in a direct line, whereas the engine must give off its power at a high speed and by a rotary motion; or in other words the quick rotary motion of the engine must be converted into a slow direct motion, before it can be applied to pulling ploughs and cultivators as at present constructed for animal power. In this connection also arises the question whether a rotary or direct motion is the best for the purpose to which it is sought to be applied.

These are points of great mechanical importance, and attracting particular attention at the present time; and may perhaps be considered desirable as the subject of a further paper on a future occasion, in which the writer will be happy to aid.

If the present paper has supplied any information or led to the expression of any opinions tending to advance the cause of mechanical engineering, the object with which it was written will be attained; and the writer has the satisfaction of contributing his mite to the proceedings of the Institution.

TABLE III.

Portable Agricultural Engines.
Results of the Trials at the Shows of the Royal Agricultural Society.
Extracted from the Reports of the Judges.

Name of Maker.	Horsepower.	Duty performed. Coal burnt per horse power per hour while doing the work.						Time of Raising Steam from cold water to 45 lbs. per square inch.					
		1849	1850	1852	1853	1854	1855	1849	1850	1852	1853	1854	1855
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	mins.	mins.	mins.	mins.	mins.	mins.
Alchin & Son	6	...	...	...	...	8·50	...	...	...	...	...	42	...
Bach & Co.	4	...	...	...	9·73	...	...	...	...	...	40	...	...
Barrett, Exall, & Andrewes	4	...	...	11·45	...	...	...	...	...	36½	...	...	...
Ditto	6	...	...	5·45	6·09	...	4·42	...	...	49	41	...	65
Ditto	7	...	10·55	...	...	...	...	...	81	...	...	...	...
Batley	6	...	13·85	...	13·53	...	...	...	85	...	43	...	...
Clayton, Shuttleworth, & Co.	4	...	...	8·40	4·32	...	...	..	...	41	47	...	...
Ditto	5	11·80	...	...	...	...	...	44	...	...	...	...	...
Ditto	6	...	...	6·00	...	5·19	...	...	...	32	...	39	...
Ditto	7	10·78	7·77	...	...	...	...	45	43	...	...	...	...
Ditto	8	...	...	...	...	...	4·05	...	...	...	...	...	44½
Crosskill	6	...	...	...	...	13·50	8·08	...	...	...	...	38	66
Garrett & Son	5	...	...	9·90	6·79	...	...	...	...	69	33	...	...
Ditto	6	11·50	11·29	7·10	...	5·62	...	63	34	32	...	39	...
Ditto	6	14·00	...	...	...	...	...	61	...	...	...	...	...
Ditto	7	...	...	...	...	...	5·61	...	...	...	...	...	44
Holmes & Son	4	...	...	...	9·61	...	...	...	...	...	45	...	...
Ditto	5	...	...	...	...	8·46	...	...	...	...	...	39	...
Hornsby & Son	4	...	...	6·05	...	...	...	...	...	47	...	...	...
Ditto	6	14·20	...	4·66	4·82	...	...	92	...	50	42	...	...
Ditto	8	...	...	...	...	4·55	4·84	...	...	...	...	40	39
Ditto	9	...	7·56	...	...	...	...	...	39	...	...	...	...
Ransomes & Sims	4	...	...	9·50	..	...	...	...	...	50	...	...	...
Ditto	6	...	...	8·03	5·50	...	...	...	...	56	229	...	...
Ditto	6	...	...	...	9·07	...	...	...	...	...	65	...	...
Ditto	7	...	...	...	...	5·10	5·05	...	...	...	...	51½	55¼
Robey & Co.	7	...	...	...	...	12·28	...	...	...	...	...	47	...
Tuxford & Sons	4	...	...	11·90	...	6·42	...	...	...	35½	...	33	...
Ditto	4	...	...	8·48	...	...	...	...	...	52	...	...	...
Ditto	6	...	11·06	...	6·51	...	...	...	90	...	44	...	...
Ditto	8	...	...	...	...	...	3·70	...	...	...	...	...	66

TABLE III.

Portable Agricultural Engines.
Results of the Trials at the Shows of the Royal Agricultural Society.
Extracted from the Reports of the Judges.

Name of Maker.	Horse-power.	Coal burnt in Raising Steam from cold water to 45 lbs. per square inch.						Wood burnt in Raising Steam from cold water to 45 lbs. per square inch.					
		1849	1850	1852	1853	1854	1855	1849	1850	1852	1853	1854	1855
		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Alchin & Son	6	...	...	...	...	...	...	...	...	...	...	...	...
Bach & Co.	4	...	...	...	17·5	...	...	...	...	...	20	...	...
Barrett, Exall, & Andrewes	4	...	...	20·7	...	...	...	...	...	20	...	...	...
Ditto	6	...	...	23·5	20·0	...	18·2	...	...	20	20	...	18
Ditto	7	...	49·2	...	...	...	...	...	20	...	...	...	...
Batley	6	...	64·0	...	17·5	...	...	...	20	...	20	...	...
Clayton, Shuttleworth, & Co.	4	...	...	29·5	17·5	...	...	...	...	20	20	...	...
Ditto	5	32·2	...	...	...	...	...	20	...	...	...	...	...
Ditto	6	...	...	22·7	...	...	...	...	...	20	...	...	...
Ditto	7	37·7	36·5	...	...	...	...	20	20	...	...	...	...
Ditto	8	...	...	...	...	...	18·2	...	...	...	...	...	24
Crosskill	6	...	...	...	...	...	30·0	...	...	...	...	...	15
Garrett & Son	5	...	...	34·1	31·3	...	...	...	...	20	20	...	...
Ditto	6	73·5	31·0	19·1	...	...	...	20	20	20	...	...	...
Ditto	6	59·7	...	...	...	...	...	20	...	...	...	...	...
Ditto	7	...	...	...	...	...	26·0	...	...	...	...	...	21
Holmes & Son	4	...	...	...	25·9	...	...	...	...	...	20	...	...
Ditto	5	...	...	...	...	...	...	...	...	...	...	...	...
Hornsby & Son	4	...	...	24·9	...	...	...	...	...	20	...	...	...
Ditto	6	46·2	...	30·2	29·5	...	...	20	...	20	20	...	...
Ditto	8	...	...	...	...	...	34·5	...	...	...	...	...	24
Ditto	9	...	42·0	...	...	...	...	...	20	...	...	...	...
Ransomes & Sims	4	...	...	24·2	...	...	...	...	...	20	...	...	...
Ditto	6	...	...	33·2	25·5	...	...	...	...	20	20	...	...
Ditto	6	...	...	...	30·3	...	...	...	...	...	20	...	...
Ditto	7	...	...	...	...	...	26·7	...	...	...	...	...	21
Robey & Co.	7	...	...	...	...	...	...	...	...	...	...	...	...
Tuxford & Sons	4	...	...	21·4	...	...	...	...	...	20	...	...	...
Ditto	4	...	...	22·1	...	...	...	...	...	20	...	...	...
Ditto	6	...	41·0	...	29·3	...	...	...	20	...	20	...	...
Ditto	8	...	...	...	...	...	28·0	...	...	...	...	...	24

TABLE IV.

Dimensions of Portable Agricultural Engines.

Extracted from the Lists of the Royal Agricultural Society.

Name of Maker.	LINCOLN, 1854.					CARLISLE, 1855.				
	Horse power.	Diameter of Cylinder.	Length of Stroke.	Number of Revolutions per minute.	Diameter of Crank Shaft.	Horse power.	Diameter of Cylinder.	Length of Stroke.	Number of Revolutions per minute.	Diameter of Crank Shaft.
		ins.	ins.		ins.		ins.	ins.		ins.
Alchin and Son......	6	8	15	120	2¾	...	...	...	... ...	...
Barrett, Exall, and Andrewes	...	...	...	... ...	...	6	8	12	110-120	2¾
Clayton, Shuttleworth, and Co.	4	6¼	12	130	2⅜	6	7	12	130	2⅝
Ditto	5	7	12	115	2⅝	8	7¾	12	130	2⅞
Ditto	6	7¾	12	115	2⅞	8	8½	12	115	2⅞
Crosskill	6	8	14	120	3	6	8	14	120	3
Garrett and Son ...	5	7½	10	110-130	3	..	...	...	... ...	...
Ditto	6	8⅜	12	100-130	3⅛	7	8½	12	120	3⅛
Ditto	7	8½	14	100-130	3¼	8	8½	14	100	3¼
Holmes and Son ...	5	7¼	12	126	2⅜	...	...	...	... ...	...
Ditto	6	8	14	126	2¾	...	...	...	... ...	...
Hornsby and Son...	4	6¼	12	150	2⅜	...	...	...	... ...	...
Ditto	6	7	18	95-110	2⅞	...	...	...	... ...	...
Ditto	6	7⅜	14	110-127	2⅝	...	...	...	... ...	...
Ditto	7	8⅛	14	110-130	2⅞	8	8⅝	14	110-135	2⅞
Ditto	8	8⅝	14	110-127	2⅞	8	9¼	14	110-135	3
Ransomes and Sims	4	5½	12	160	2¼	5	6	12	160	2¼
Ditto	7	7	10	150	2½	7	7	11	150	2½
Robey and Co.	7	8½	12	120	2¾	...	...	...	... ...	...
Tuxford and Sons	4	6	10	150	2¼	4	6	10	135	2¼
Ditto	5	6½	11	142	2¾	...	...	...	... ...	...
Ditto	6	7	12	135	2½	6	7	12	135	2½
Ditto	8	8½	12	135	2¾	8	9	12	125	3

The **Chairman** considered they were much indebted to Mr. Waller for his interesting and valuable communication, the preparation of which must have involved no little time and trouble. This was the first paper that had been brought before the Institution on the subject of steam power as applied to agriculture, which was one of such importance as to deserve special consideration at the present time.

Mr. **Forsyth** remarked that the earliest date that had been mentioned of the portable engine was 1839, but he remembered an application of an old locomotive engine in 1838 as a portable engine; the "Meteor," the second locomotive of the Liverpool and Manchester Railway, was sold at that time to a tenant of Lord Wharncliffe, to work on a colliery near Redcar, where it was employed for several purposes in place of horses.

The **Chairman** thought it highly probable that the first introduction of the portable engine for agricultural purposes was due to the use of it as a colliery engine.

Mr. **Waller** said that in considering the application of steam power to agricultural purposes, the paper had been limited to the portable engine, that is, an engine mounted on wheels to be drawn by horses from place to place; and as far as he could ascertain, the first portable agricultural engine was constructed in 1839. He had found however that steam power had been employed in such a connection as early as 1796, at Trentham, in Staffordshire.

Mr. **Chellingworth** had noticed considerable variety in the modes of construction of agricultural engines; in many instances cast iron had been substituted for wrought iron in several parts of the engine, for reduction of cost in construction, and Messrs. Bach, of Birmingham, had made crank shafts of cast iron, but he believed they had been found objectionable, as their weight was too great, when made of the requisite strength, causing the engine to rock in working. He understood that Mr. W. Dean, of Birmingham, was constructing an engine on an improved principle, in which the cylinder was placed in the smokebox, exposed to the waste heat from the fire, and not surrounded by a jacket.

Mr. **Allen** enquired what the pressure of the steam was in the earlier agricultural engines, and what pressure was now generally employed. He further enquired what pressure Mr. Waller's experience had led him to believe the most economical in practice; and also what degree of expansion he would recommend. He believed Mr. Bethell, of London, was making engines intended to work at

150 lbs. pressure per square inch. The results obtained from engines were imperfect in point of economy, unless a high pressure of steam were employed, with a corresponding degree of expansion.

Mr. WALLER replied that 45 lbs. per square inch was the pressure first fixed by the Royal Agricultural Society; if during a trial the pressure fell below 38 lbs. per square inch, the engine could not maintain the speed, and either was stopped till 38 lbs. pressure was reached, or had so much time in excess of duty; and if the pressure rose above 48 lbs., the engine was made to blow off by raising the safety valve, causing a loss of steam and waste of fuel in either case. The limit of pressure was now fixed at 50 lbs. per square inch, but he thought it might be increased to about 70 lbs. or 75 lbs. to obtain the most advantageous results. He believed Mr. Bethell was aiming at a pressure even as high as 200 lbs., but this involved the necessity of heavy machinery and a superior engineman, and it was not desirable in ordinary farm work to have anything beyond the management of a common labourer.

The portable agricultural engine was in many respects similar to the locomotive, but there were several important distinctions that might be mentioned, particularly the removing of the gearing to the top of the boiler, and placing it entirely outside; also the position of the cylinder in the upper instead of the lower part of the smokebox. The position of the cylinder in the smokebox had already been claimed as an original invention by several parties, but the idea was evidently taken directly from the general type of the locomotive engine, and could not properly be claimed by any one at the present day. With regard to the use of cast iron, to which allusion had been made, it had been laid down as a principle by the Royal Agricultural Society that wrought iron should be freely used wherever practicable, and always in preference to cast iron.

Mr. ALLEN noticed that in several of the drawings of boilers that had been exhibited, the tubes had been shown set at a greater distance apart in the lower than in the upper rows; but he thought it was generally considered preferable to have the wider spaces at the top, in order to favour a free escape of steam, the steam generated at the lower tubes having to pass upwards between the upper tubes.

Mr. WALLER explained that in agricultural engines the converse view of the question was taken, and it was argued that the lower tubes should be wider apart to allow of a free deposit of mud, the mud separated at the upper tubes having to pass down between the lower. This arrangement was necessitated by the dirty water used for the engines by farmers, who frequently filled the tubs from which the boilers were fed with the water out of their dung-ponds, causing often the accumulation of a mass of mud after a few hours' work; he had seen an instance where the firebox was burnt out with less than six months' work. In the earlier agricultural engines the spaces between the tubes had been made uniform, in accordance with the ordinary practice, and the wider spaces between the lower tubes were first introduced, he believed by Messrs. Clayton in 1854, in consequence of the brackish water found in the neighbourhood of Boston and in the fens, and the plan was then adopted in engines intended for other parts of the country also. In the commercial engines, the smallest distance between the tubes was ⅝ inch or ¾ inch clear between the tubes, or 1 inch where it was intended to use salt or brackish water; and this space was increased in many engines to 1⅛, 1¼, and 1⅜ inch in the lower rows, the usual space in the upper row being about ¾ inch.

Mr. **Siemens** considered that the performances of the portable engines that had been stated presented results surpassing those obtained from either marine or stationary engines, excepting the Cornish engines, where however the peculiar circumstances attending the working of the engines gave them special advantages over all other classes of engines. The remarkable performances of portable engines that had been announced at the various competition trials appeared however to have been obtained from racing engines, and there were several important differences between racing and commercial engines, which it was necessary to bear in mind in considering the published statements of duty. In the racing engines, the moving parts were all made with a view to extreme lightness, and great care was taken to diminish friction as much as possible; simple pistons without packing were accordingly used, and a greater number of thin and close packed tubes in the boilers. In some of the engines that had been noticed, the cylinder was placed in the smokebox, instead of on the back of the boiler, and the heated atmosphere to which it was in this manner exposed would certainly cause the steam to be superheated, and be advantageous in preventing condensation from cooling in the passage to the cylinder.

The **Chairman** thought the results obtained by the racing engines were remarkable, considering the difficulties that had to be encountered, rivalling as they did the performances of the Cornish engine. In many of them it appeared that only 3½, 4, or

4½ lbs. of coal per horse power per hour were consumed, and ordinarily 5½ or 6 lbs. were sufficient. The consumption of the commercial engines would however be above these amounts, and he enquired what results were generally obtained in commercial engines.

Mr. Waller replied that 7 lbs. per horse power per hour of ordinary hard Yorkshire coal was generally required by commercial engines, including raising steam and leaving a margin for contingencies. At the trials of the racing engines, Welsh coal was supplied to them, of which a less quantity would be sufficient than of Yorkshire coal; he did not know exactly their relative evaporating value, but in an experiment with one of the racing engines 3¾ lbs. per hour of Welsh coal had been found equivalent to 4¾ lbs. per hour of the Yorkshire coal. The high duty that had been noticed could be obtained only from racing engines, and the makers would not dare to issue such engines for actual working, on account of the great risk in working them, and the need of an experienced engineman to attend to them. In some of the latest racing engines, the water space round the tubes had been reduced to less than ¼ inch, the tubes being made very thin at the same time, and at the sides of the boiler the tubes were placed as close to the shell as the rivet heads would allow, with only ¾ inch for the water space even at the bottom. In a boiler 2 feet 6 inches diameter there had been 89 tubes, 2 inches diameter; and in another boiler 2 feet 8 inches diameter the number of tubes was 61, and their diameter 2¾ inches, while another was made with 41 tubes, 3¼ inches diameter, leaving not much water space in either case.

Mr. Greaves remarked that it was desirable to register the quantity of water evaporated, as well as the amount of coal consumed, in order to form a correct estimate of the performance of the engine, and for this purpose it would be advisable to attach a meter to the feed pump of the engine. He had adopted this plan for some time at the engines of the East London Water Works, and found it gave much useful information; a little more than 1 gallon of water was evaporated by 1 lb. of Welsh coal or coke, and the consumption was 2½ lbs. of coal per horse power per hour, reckoned on the water actually lifted.

The Chairman thought that the present limit of 50 lbs. pressure, fixed by the Royal Agricultural Society, could not remain the maximum for long; the progress that was being made in other classes of engines by the use of higher pressures would induce an alteration in the case of agricultural engines also, and an increase of pressure had already been strongly advocated by many engineers of eminence.

He observed that great trouble had evidently been taken in the preparation of the valuable and interesting paper that had been read, and moved a vote of thanks to Mr. Waller, which was passed, expressing the hope that the subject would be continued in a supplementary paper on the application of steam power to the various machines employed for agricultural purposes.

The following Paper, by Mr. Thomas Forsyth, of Manchester, was then read :—

DESCRIPTION OF A DOUBLE TRAVERSING DRILLING AND GROOVING MACHINE.

The machine described in the present paper has been designed for the purpose of extending the facilities and advantages of machine work, in shaping and sinking recesses, cutting out keyways or other holes, and various similar kinds of work, and consists of a compound drilling machine, having a self-acting double traversing motion, and a peculiar arrangement of tools, adapting it to various forms of work.

The new machine is shown in Figs. 1 to 4, Plates 62, 63, and 64.

Fig. 1, Plate 62, is a plan of the machine.

Fig. 2, Plate 63, is a front elevation, some of the parts being shown in section.

Fig. 3, Plate 64, is an end elevation, and Fig. 4, a transverse section.

AA are stands resting upon the floor and supporting the bed B, on which are mounted the adjustable tables CC, and the traversing drilling headstocks DD, with their gearing, which receives motion from the straps EE, by which the two headstocks of a double machine are driven independently of each other. The revolving motion of the cutting tools is communicated from the shafts FF through ranges of toothed wheels in the usual manner, variations of speed to suit different sorts of work being obtained by the cone pulleys GG driven by corresponding pulleys on the shafts above.

The reciprocating and feed motions are communicated from the shafts FF by cone pulleys HH and straps I, whereby the rate of traverse and feed can be adapted to various kinds of work. The range of reciprocation is governed by fixing the pins of the connecting rods KK in the required positions in the slots formed on the upper surface of the elliptical toothed wheels L, and the velocity of horizontal traverse of the headstocks DD is rendered nearly uniform throughout the entire stroke by the combination of elliptical toothed wheels L with eccentric toothed wheels M, as shown in Fig. 5, Plate 62, the eccentric wheel making two revolutions for one of the elliptical wheel.

The feed motion is transmitted from the elliptical wheels L to the drill spindles NN by ranges of gearing including friction plates OO. The downward feed of the tools is made at the end of the reciprocation, at which time the headstocks DD are travelling at their minimum velocity.

To obtain great steadiness of the drills, the bosses in which the drill spindles slide are made of considerable strength, and the drills as short as the work will admit of, so that while drilling to any ordinary depth the ends of the spindles do not protrude far below the bottoms of their sockets, and nearly the same distance is preserved from the point of support to the cutting point during the entire process. Conical bearings with tightening nuts are adopted, so as to allow of correction for wear and tear of the parts.

In order to ensure standard dimensions of work corresponding to the dimensions of the tools, it is necessary that the centre lines of the cutters be perfectly in line with the axes of the drill spindles; and to effect this adjustment accurately, the sockets in the drill spindles should be made conical and screwed at the bottoms, the drills having corresponding screws and conical fitting parts; cotters also will answer the same purpose as screws to draw the drills tight up in their sockets.

The drills are not of the form generally used in other machines, but have their cutting parts at the circumference only. In order to preserve uninjured the standard dimensions of work, it is in practice found desirable to rough out the work previously to nearly the size intended, by drills which may be sharpened from time to time when necessary during the progress of the work; and then to finish it by standard "rose bits," which will last for a great number of pieces of work without any perceptible alteration in their dimensions.

If a cross traverse is required, it can be given by a self-acting motion applied to the transverse slides on the tables holding the work, in which case the longitudinal traverse of the drill headstocks would be suspended. If other than straight grooves are required, they may be obtained by combinations of the longitudinal traverse of the headstocks and the cross traverse of the tables, both going on at the same time. If circular grooves or portions of them be required, they may be obtained by the use of self-acting revolving tables, in connection with the ordinary tables for holding the work.

It has been thought unnecessary to enter into a description of all the details of the machine, but enough has been stated to explain all the more important particulars.

The new machine has been in operation at the works of Messrs. Sharp, Stewart, and Co., in Manchester, for about five months, and after a daily experience of its working during that period, it is believed that in the quality of the work produced, and the cost and rapidity of production, it is superior to any other machines previously used for the same purposes. It has been found that the cost of the work done on the machine, as compared with former processes, has been reduced on an average about 90 per cent., the same work being now done for £10 that cost £100 before, whilst the rapidity of production with the same expenditure of wages has been increased about 8½ times, and the writer believes that the quality of the work has not been equalled by any other machine for similar purposes.

The largest machine yet ordered is now in course of construction, and a duplicate of it will shortly be sent to the Crystal Palace at Sydenham. The principal dimensions are as follows :—

Length of bed	12 feet.
Range of headstocks	3 feet 8 inches.
Length of slot drilled	13 inches.
Depth of slot	11 inches.
Width of slot	4½ inches.

Extreme distance apart at which drills can work, 8 feet 9 inches.

The numerous purposes to which these machines may be applied will readily suggest themselves; for instance, one drill may be slotting or surfacing, and the other drilling plain holes; or both may be drilling plain holes, slotting, or surfacing, as required. They have been used for such work as cutting cotter holes in locomotive connecting rods, both ends at the same time, cotter holes in connecting-rod straps, in pistons, piston-rods, and crossheads ; for cutting key-grooves in shafts ; for cutting oil-cups and joints of motion-work out of the solid, and oil-ways in bearing brasses ; and for various other similar purposes in connection with locomotive engine building and engineering tool making generally.

The great advantage of these machines is perhaps best seen in the difficult and tedious operation of cutting slots or cotter holes, and from the samples exhibited it will be observed that the work produced is far superior in accuracy and finish to that done by the usual process of drilling, slotting, and filing ; and this advantage is obtained in addition to the economy in cost and time of production.

Another feature worthy of notice is the little attention the machine requires after starting ; a man and a boy can with ease look after two double machines.

It is important to observe further, that in contrast with most other workshop tools, no time is lost during the execution of a piece of work by this machine, but the work progresses without intermission from the commencement to the completion.

Mr. FORSYTH exhibited several specimens of cotter holes of different sizes made by the machine, together with the tools by which they were cut; and also a specimen of a cotter hole cut by hand in the usual manner, the hole being 6 inches long, ⅞ inch wide, and 6¼ inches deep, which he stated had been produced in 52 hours at a cost of £1 2s. 2d., three files being entirely used up in the work, whilst by the machine the same sized hole was cut in less than 14 hours by a single drill at a cost of only 2s. 0d.

The CHAIRMAN thought the machine was an admirable tool for the work intended, and the great saving effected by it, combined with the superior quality of the work produced, would render it a valuable addition to the workshop, as all must be aware of the difficulty and expense of cutting slots by the ordinary process, which required much subsequent fitting.

Mr. FORSYTH said it must be observed that the plan of slot drilling by machinery was not novel, having been in use now for about eight years at Messrs. Sharp's works; they had had one of Haley's machines at work about two years, and another by Nasmyth about a year. The originality of the present machine lay in the use of a reciprocating drilling headstock moving on a slide or bed, the work to be operated upon being stationary but having facilities for adjustment as in an ordinary shaping machine. This idea was first suggested by Mr. Furnival, a foreman at Messrs. Sharp's, and the detail was subsequently worked out by Mr. Batho, one of their assistants, by whom mainly the machine had been brought into its present form. In the first machine made, a simple crank motion was employed to give the headstocks their traverse, but this could be driven only at such a speed as that the maximum velocity of the headstocks at half stroke should be below that at which heating of the tool would commence, making the average velocity throughout the stroke considerably less than at present. In the machines subsequently made, the combination of eccentric and elliptical toothed wheels was introduced, by which a nearly uniform velocity of traverse was obtained, and the headstocks were driven at the maximum velocity throughout the stroke, giving nearly twice the average speed previously attained. The castings used in the machine were all of the hollow or box description, combining lightness with strength; and the upper part of the headstocks was cored out to form a large oil vessel, as shown in the drawing, by which a constant feed was supplied to the drills. In the ordinary mode of fixing the drills in the drill spindles, the drill was made parallel in the shank, fitting into a parallel socket in the spindle, and tightened by a set screw; this had the effect of throwing the drill slightly out of centre, and gave it an irregular motion, which produced an enlargement of the hole at the extremities. To obviate this defect, the shank of the drill used in these machines was made slightly conical, fitting into a conical socket in the drill spindle, and drawn up tight by an end screw.

The CHAIRMAN enquired how long the drills were found to last, and what was the largest size of tool that could be used in the machine.

Mr. BATHO replied that the drills were found to be very durable; one 2 inch drill had lasted a week, and then only wanted sharpening again, and one rose bit or finishing tool lasted six weeks without sharpening, though constantly at work every day; an ordinary large cotter hole, say 6 inches long and deep and 1 inch wide, would use up three files, costing 5s. 0d. at least, but these drills being made with a small cutting face could be quickly rubbed up on an oil stone, and consequently were very durable. The present machine was constructed for a traverse of 12 inches, and the largest single drills would cut a hole 2 inches wide and 5 inches deep: for holes wider than 2 inches it was preferable to use an expanding bit or chuck, formed of a boss having diagonal grooves in its face, in which two cutters could be fixed at the required distance apart; by this means a hole had been cut as wide as 4½ inches.

Mr. SIEMENS observed that such an arrangement of an expanding bit would afford a good means of adjusting the cutters when worn.

The CHAIRMAN expressed much pleasure and interest in the machine, which he thought supplied an important desideratum in the list of engineer's tools. He proposed a vote of thanks to Mr. Forsyth, and requested that he would leave in the Institution for reference some of the specimens of work and tools that had been exhibited.

The following Paper, by Mr. C. William Siemens, of London, was then read:—

ON AN IMPROVED WATER METER.

In January, 1854, the writer communicated to this Institution a paper on an improved Water Meter, in which he described several mechanical arrangements, by which he had succeeded in measuring water flowing through pipes, with a sufficient degree of accuracy for practical purposes, and without destroying the pressure or head of water column. In the course of considerable experience with these meters, several important improvements have suggested themselves, and opportunities have occurred of observing the public importance of supplying water by meters, which the writer thinks may not be without interest to the members of this Institution.

The chief difficulty that presented itself in endeavouring to produce a practically perfect high pressure meter was not so much to obtain a correct measurement under varying circumstances of pressure, as to render the instrument sufficiently durable to resist for years the action of the water and of the impurities carried along with it. It was found necessary to protect all the working parts against the chemical action of the water, to prevent deposit of calcareous matter upon the measuring apparatus, and to combine strength with lightness as far as possible in the construction of the movable parts, in order that they might resist the force of a high water column, and might yet be moved by the slender stream produced by a leaky tap, which in the case of the smaller meters may not exceed half a pint of water passing through per minute. Cheapness and compactness of construction were other important considerations not to be lost sight of.

The improved meter, as at present manufactured by Messrs. Guest and Chrimes, is represented one quarter full size in Plate 65, Figs. 1, 2, and 3.

The meter consists of a cast iron casing A, Fig. 1, divided by a partition into two compartments B and C. The water entering the compartment B through the pipe D passes through a spout E into the revolving drum F. The drum F, shown in the perspective view, Fig. 2, and the plan, Fig. 3, is formed of two stamped disks of brass plate rivetted and soldered together face to face, each part containing similar spiral grooves or corrugations forming channels for the water to pass from the centre to the circumference. The foot of the spindle G forms with the lower portion of the drum a chamber H, into which enters a fixed stud J. The point of the stud is of hard steel, and works in contact with a bit of hardened steel let into the bottom of the spindle G, forming a support for the drum F. The chamber H is filled with oil to protect the bearing from the action of the water, and the oil being the lighter fluid cannot be displaced by the water. The drum F carries three or more flat blades KK, intended to produce a resistance in the water increasing as the square of the velocity of revolution, the effect of which is that the drum, which has a tendency to revolve at a rate increasing more rapidly than the velocity of the water, is caused to rotate at a speed proportionate to the quantity of water passing through, whether at a high or low velocity.

The water having issued into the chamber C passes away by the pipe L to the point of delivery. The spindle G passes upward into the chamber M, which contains wheel work to reduce the motion communicated by the drum and is also filled with oil. A small spindle passes finally at a greatly reduced speed through a stuffing box into the upper chamber N, containing the dial on which the quantity of water that has passed through the meter is indicated by hands in gallons or cubic feet. The details of the counting apparatus have been described in the former paper. The cup or dish forming the chamber M is made of stamped brass and corrugated, in order to yield to concussions from the water.

Before entering the meter, the water has to pass through a grating O, which arrests any solid matter, and is made easily accessible for the purpose of removing from time to time the impurities that have collected, when it is found that the passage of the water is obstructed.

It is important to make the area of the inlet E nearly equal to the collective area of the outlets of the drum F, but a little smaller than the latter. If the area of the inlet were made larger than that of the outlets, there would be a greater pressure within the drum than in the surrounding chamber C, and some water would escape unmeasured between the neck of the drum and the outside of the inlet E; on the other hand, if the area of the inlet were made considerably smaller than that of the outlets, a leakage would take place from the chamber C into the drum, because the water passing through E would act in the manner of a blast or as in Mr. James Thompson's jet pump. The area of the inlet should accordingly be for the smaller meters 10 per cent., and for the larger 5 per cent. less than that of the outlets, to allow for loss of velocity by friction in the drum. This loss may be taken to represent with tolerable accuracy the degree of obstruction opposed by the meter to the moving water column. The rapid current of the water through the inlet E and the curvilinear channels of the drum has been found to prevent deposit of calcareous matter in these places, which is an important point, for were it otherwise, the meter would gain in relative speed in proportion as the area of the channels was diminished.

Meters constructed on this plan have now been found to work continuously for nearly three years under the most varied circumstances without requiring any alteration whatever. The arrangement made between the manufacturers and the water companies or purchasers of the meters is that every meter that fails to give satisfaction, in consequence of stoppage or inaccuracy of measurement, shall be exchanged; and experience shows that the number of meters so returned does not exceed 2¼ per cent. in the year, and these for the most part have been sent back only from trivial causes. The more serious accidents have been that the meter has become choked with gravel or other impurities, that had entered through a broken grating; or that the regulating vanes have been broken, and the relative velocity of the revolving drum has been much increased; or that some derangement in the wheel work of the counting apparatus has taken place. In winter it has happened that the casing of the meter has been burst by frost, but this class of accidents does not concern the mechanical arrangements of the meter. The manufacturers enter into contracts to maintain the meters supplied by them in good working condition for a term of years, in consideration of the moderate annual charge of 5 per cent. per annum on the first cost, proving thereby their own confidence in the durability of the meters.

A further object of this paper is to prove from actual experience the utility of the meter to water companies and water consumers, and to engineers and others for general purposes.

Although the meter has been as yet but partially applied by water companies as the arbiter between themselves and their irregular or trade customers, the advantages to the companies from prevention of waste, error, and fraud, have been made manifest. The following Table gives the results of the application of fifteen meters, showing the difference between the rate paid previous to their application and the established value of the water actually supplied according to the meters :—

Number of Reference.	Rate Paid.	Value of Water Consumed.
1	£40	£1050
2	40	400
3	50	450
4	40	78
5	35	64
6	18	500
7	365	500
8	15	45
9	7	21
10	7	21
11	7	21
12	20	95
13	12	110
14	13	115
15	16	700
Total...	£685	£4170

It appears from this table that the collective rates paid by 15 consumers amounted to £685, whereas according to the established value of the water they ought to have paid £4170, or more than six times the amount. These are no doubt exceptional cases, which have come particularly under the notice of the manufacturers because the correctness of the meters was disputed by the consumers; but they show the utter impossibility of estimating the quantity of water supplied by a given pipe without the application of a meter. In several of the cases stated in the table, the consumers themselves applied for the meter, because they thought the rate they paid was excessive. They calculated no doubt correctly the water actually required for their manufacturing operations, but did not take into account the lavish waste that is continually going on by taps leaking or left open, by broken pipes, and by inundating instead of washing floors and utensils, &c. From all the information the writer has been able to collect, he ventures to affirm that fully one half of all the water supplied by the permanent supply system, which at present is made compulsory by Act of Parliament, is absolutely wasted, without utility either to the consumers or to the water companies. It cannot even be said that the water thus wasted is useful in a sanatory point of view, by cleansing the sewers, because the deposit contained in the sewers can be removed only by flushing them from time to time.

The value of the water that is so wasted may be estimated from the fact that one Water Company alone, the East London, sells at present nearly 800 millions of gallons a year by meter, which at the price of 6d. per 1000 gallons amounts to a rental of £20,000 per annum. They employ for this purpose only about 200 meters, which are however of more than the average dimensions.

In order to detect and prevent all waste of water, it would be necessary to apply a meter not only to the branch pipe of every irregular consumer, but also to every branch main supplying a district or a street. The legitimate consumption of each district or street would then be soon ascertained, and if in any one week it exceeded that amount, the meter would at once draw attention to the fact, the cause of which would frequently be found to be a leakage from the branch main underground into the sewers, which it is at present impossible to detect.

In order to render the system of supply by meter perfect, it should be extended also to private houses. Objection has been raised against this proposition, on the ground that the poorer housekeepers would economize water with detriment to their own sanatory condition, and also that the cost of the meter is too high in proportion to the amount of rent they pay. These objections are applicable however only to the case of labourers' cottages, which indeed might be supplied without restriction, or might be charged a fixed rate till their consumption exceeded a certain maximum. It should however be borne in mind that the principal value of meters to water companies consists in the prevention of waste; and it is a question open for discussion, whether the waste going on in houses on the permanent supply system does not far exceed the cost of maintenance and investment of a meter, which indeed would not be more than the cost of the present cistern and ball taps.

A system of supply by meters would relieve the officers of the water companies from much watchful care and unpleasant discussion with the customers about the quantity of water they consume. The advantages derived by consumers from being supplied by meters are,—first, that each consumer pays only for the water actually used by him, whereas at present he must pay also his share of all the waste that is going on;—secondly, the meter is useful to the consumer for regulating the distribution of water on his own premises, and for preventing waste by his own servants;—and thirdly, the general prevention of waste will enable the water companies to reduce their charges.

There are many other useful applications of an efficient, cheap, and compact water meter, one of the most important of which is the application to steam boilers. By inserting a meter into the suction pipe of the feed pump, a correct indication is obtained of the water actually evaporated, which serves as a check on the one hand upon the performance of the engine, and on the other hand upon the quality of the fuel employed, or the care of the fireman in burning it.

There are at present upwards of 2000 of these meters in constant use at several large towns in this country, including London, Bristol, Edinburgh, Newcastle, Yarmouth, and Leeds; and also upon the continent, at Berlin, Amsterdam, and elsewhere.

The sizes of the meters vary from $\frac{1}{2}$ inch to 12 inches diameter of supply pipe; and excepting the comparatively few cases of defective meters above alluded to, which, according to a careful register kept by the manufacturers, have amounted to not more than 33 cases in a year out of about 1500, the results have been highly satisfactory as regards both the correctness of measurement and the durability of the meter.

Mr. Siemens exhibited several meters of different sizes, and specimens of the revolving drums, from the smallest size, with a drum $1\frac{1}{2}$ inches diameter, intended for a pipe $\frac{1}{2}$ inch diameter, delivering 5 gallons per minute, up to one of the largest sizes, with a drum 8 inches diameter, intended for a main 10 inches diameter, delivering 500 gallons per minute. A $\frac{1}{2}$ inch meter was also exhibited, and shown in operation to the meeting at various rates of discharge, having a glass casing allowing the motion of the rotating drum to be seen while in action.

The Chairman observed that there had been hitherto much difficulty in obtaining a correctly registering meter, and now that water was so much more generally introduced by water companies into houses, &c., it was important to have an accurate and durable meter, that could be fully relied upon.

Mr. Allen enquired whether the drum would make many revolutions by its momentum after a sudden stoppage of the discharge; he thought that it would be liable to do so, especially under a high pressure or a great velocity, and that the meter would then register too large a quantity.

Mr. **Siemens** replied that the tendency of the drum to overrun, when the discharge was stopped, was now successfully prevented by the retarding vanes fixed upon it, by the resistance of which in the stationary water it was speedily brought to rest. It had been ascertained by experiment, that when the drum was rotating at 2000 revolutions per minute, only 5 or 6 revolutions were made by it after the discharge had been suddenly stopped; and the little error arising from this cause was nearly compensated for by the effect produced by the inertia of the drum at the commencement of motion, a small quantity of water having to pass through the drum not registered, before the drum had obtained the velocity corresponding with the velocity of the water through the meter. As an extreme test, he might mention an instance in which a meter had been used to measure the water supplied to an engine boiler, and had been placed between the feed pump and the boiler, and consequently the drum was set in motion and stopped at each stroke of the pump, and went with jerks; but even under this severe trial the meter was found to register only about 5 per cent. in excess. In such a case it would be necessary to provide an air vessel to equalize the flow through the meter; but even without such an addition the amount of loss at each stoppage was evidently very small.

Mr. **Greaves**, of the East London Water Works, was particularly glad to be able to bestow praise on the present invention, having so often been unable to form a favourable opinion of water meters. He had paid considerable attention to the several meters that had been brought forward, and the first that occurred to him as having been practically useful was that by Stirling, whose meter was formed of a horizontal revolving drum; this was however found faulty, and could not be used under high pressures. The original screw meter, invented by Mr. Siemens, had proved defective. Piston meters, consisting of a piston driven up and down in a cylinder by the water, which was admitted alternately at the top and bottom of the cylinder, had been frequently attempted, but unsuccessfully. Trials had also been made of double chambered meters with door pistons, which might be said to consist of a pair of coupled engines worked backwards; but elastic diaphragms as used for gas were not suitable for water. In Siemens' new meter, now under consideration, the measurement of the water depended on the principle of reaction, the drum being caused to rotate by the reaction of the water in passing through it. After having experimented carefully on all the above meters, he had found that of Mr. Siemens to be the best, and it had proved very satisfactory in working. Of the other meters he preferred that by Kennedy, of Kilmarnock.

The great difficulty to be encountered had been to produce a meter that would answer equally well under all varieties of pressure and velocity, and would transmit the full pressure of the water. He believed the previous meters had failed of accomplishing this fully, but it appeared to be attained in the present instance. In Mr. Siemens' meter, the addition of the retarding vanes on the drum was an important point, as the increasing resistance they encountered from the water checked the drum, and counteracted the tendency that it had to rotate at an increasing speed, which would otherwise produce an error in the registration. At the East London Water Works a large number of these meters of various sizes were being used at the present time, of which 16 were ½ inch, 18—¾ inch, 31—1 inch, 16—1¼ inch, 17—1½ inch, 43—2 inch, 17—3 inch, 7—4 inch, and 2—6 inch. The total quantity of water supplied through these meters was 2,000,000 gallons per day, at a minimum value of 6d. per 1000 gallons, and a correct measurement was therefore a matter of great importance, this being he believed a larger quantity of water than was measured through meters by any other parties, although he understood that Mr. Bell, of Bristol, was using a greater number of meters.

The defects that had come under his observation in the working of the meters had not been serious, and were defects in construction, not in principle; in the earlier meters some of the drums and the retarding vanes had been broken, the spindles burred, or the gearing of the counting apparatus injured, but there had been very few stoppages of the later made meters from any causes.

The Chairman enquired for how long a period he had been making trials of the different meters that had been introduced, and how long he had had Siemens' meter in regular use.

Mr. Greaves said that the East London Water Works Company had been occupied for 15 years in experiments on meters, in which about £1000 had been expended. His predecessor, Mr. Wicksteed, had taken great pains to arrive at a satisfactory meter, but without success, and had himself made a machine for the purpose, having a double set of double-beat valves, forming in fact a water pressure engine. Other meters also were made fitted with slides, but it was found difficult to adjust the working of the tumblers to the varying pressure, and the apparatus proved noisy and inconvenient. It was essential to any meter that was to be generally adopted that it should not be troublesome to the consumers, or they would not use it. He had now had the meter of Mr. Siemens in its improved form in regular use about twelve months, and it appeared to fulfil all the requirements of a good and durable meter. It was important that in case of any injury or stoppage of the meter the consumer should not suffer thereby, and in this respect there was an objection to all piston meters, for though they might register equally accurately with others whilst in working order, yet if ever they happened to break down the flow of water was stopped; in Mr. Siemens' meter on the other hand, if a break down occurred, the flow of the water was not interrupted, and the loss was entirely on the side of the company. In the case of some manufactories, such as sugar works, much damage had been known to accrue from an accidental stoppage in the supply of water, and it was desirable to avoid the serious consequences of such an accident, even at the expense of some loss of water charge from the meter standing still a day or two, the principle in every instance being that the meter ought to break down against the company, and not against the consumer.

Mr. **Bell**, of the Bristol Water Works, said he had used a large number of the meters described in the paper, and had been well satisfied with them; he had brought one of them for the purpose of showing at the meeting the actual results of working. The meter was now for the first time taken to pieces since first putting to work, having been in constant work for two years, and it was found in complete good order with very slight signs of wear in any parts, after having measured many thousand gallons of water. It had been used at first at a sugar house, and when tested on being removed from the house gave about 2½ per cent. against the company; it was replaced by another meter in about five minutes, and was then taken to the Clifton Baths, and after being used there for some time longer was again tested, when it was found to be less than 3 per cent. in error against the company, registering 972 gallons instead of 1000. The meters that he used were all tested by means of a 1000 gallon tank, the contents of which were run out through the meter, and the indication noted. It was necessary in Bristol to be very careful in the use of meters, as the water had previously been much wasted, and a sea of water would be needed to supply all the waste that would otherwise take place, no springs being sufficient.

He had tried the improved meters of Mr. Siemens under pressures varying from 25 to 50 and 60 lbs. per square inch, and had found them equally correct under all; he had now 326 of them at work, some having been down two years, and used 1 inch meters to supply 2000 gallons per hour, and ½ inch meters for 400 gallons per hour. He had tested several other rotary as well as piston meters, but none of them were quite satisfactory, as some water was allowed to pass through without being measured; in the piston meter, the cock by which the entrance and discharge of the water was regulated, was of large size, and he had found it sometimes happened that the tumbler had not power enough to turn the cock over, causing the meter to stand still, and stopping the flow of water.

Mr. FORSYTH enquired whether the rolling packing ring used in Kennedy's piston meter had been found to be durable; it appeared an ingenious way of getting over the difficulty of packing in a piston meter with little friction, and he had understood it had proved successful.

Mr. BELL replied that he had not had sufficiently long experience of the rolling packing ring to ascertain its durability, having found the meter was not satisfactory in accuracy of measurement.

Mr. CHRIMES remarked, as the maker of the meter, that the specimen exhibited by Mr. Bell had been made on the old pattern at an earlier period of the manufacture, and many improvements in detail of construction had been introduced since that time; the drum was now made of stamped corrugated metal, and considerably lighter, and being well balanced all round it was probable that the spindle barely touched the sides of the socket at a high velocity of rotation, coming in contact with the socket only at a slower speed. The bearings of the spindle were now increased to nearly 3 times the original length, in order to prevent the slight wear that was perceptible in the old specimen that had been exhibited. He might mention an unusual experiment that he had recently made, which showed the applicability of the meter to the smallest pressures; in this case, the Lancashire and Yorkshire Railway Company required a meter to measure water out of a canal into a reservoir, which when full was level with the canal, and there was found to be a variation of measurement of only 2 per cent., when the difference of level was reduced to only 3 inches, showing the correctness of measurement under a head of water of only 3 inches as well as under one of 150 feet.

Mr. BELL said he had tried a somewhat similar experiment with a 2 inch meter, causing 1000 gallons of water to pass through it, first in 16 minutes, then the same quantity in 2½ hours, and lastly the same quantity in 16 hours, and under these great variations in the velocity of the water the meter registered only 13 gallons less than the correct amount 3000, being an error of less than $\frac{1}{2}$ per cent. and in favour of the consumer.

The Chairman enquired what oil was used to lubricate the spindle of the drum, a material being required that would continue uniformly liquid, and he thought common oil would not answer in this respect.

Mr. Siemens said that common oil was not suitable, but any oil might be used that was not acid, so as not to act upon the brasswork; pure olive oil and neat's foot oil answered well, or the oil extracted from peat. As a further precaution against corrosion the brasswork was tinned, and the success of the result was shown in the meter exhibited by Mr. Bell, which he had not seen before, and in which there was scarcely any wear after two years' work. This result might appear remarkable, considering the high velocity of the drum, but he thought that the higher the velocity the less wear there would be upon the bearings, because the drum would spin round in the manner of a top or gyroscope and require in that state no lateral support whatever.

Mr. Chrimes remarked that the oil was not required to lubricate the spindle, but was necessary merely to prevent the water entering that part of the meter and producing a calcareous deposit on the bearing of the spindle; this purpose was indeed now effected with equal success by employing distilled water, but he preferred to continue using oil.

The Chairman thought the practical information that had been given in relation to the subject was very valuable; and the meter described in the paper reflected great credit on the skill and perseverance of Mr. Siemens.

He proposed a vote of thanks to Mr. Siemens for his paper, which was passed.

The Chairman announced that the next Meeting of the Institution would be a Special Meeting in Glasgow, on Wednesday, 17th September, and it was intended to be the commencement of regular periodical meetings in that place.

The Glasgow Meeting had been taken up with great spirit by many gentlemen in that city, who seemed determined to give a cordial reception to the English engineers; and he hoped as many as possible of the Members would make a point of being present.

It was proposed to hold the regular Manchester Meeting in December, as before; and next year to hold another meeting, probably at Newcastle, in addition to continuing the Glasgow Meeting.

The Meeting then terminated.

STEAM RIVETTING MACHINE.

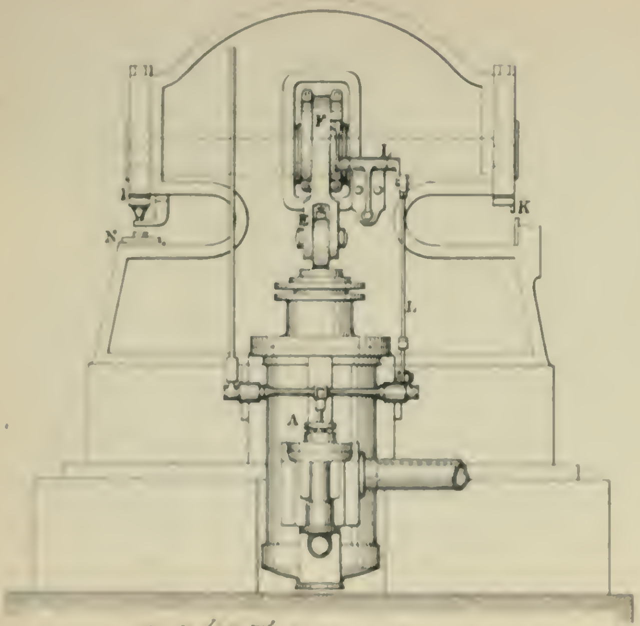


Fig. 1. *Elevation at Back.*

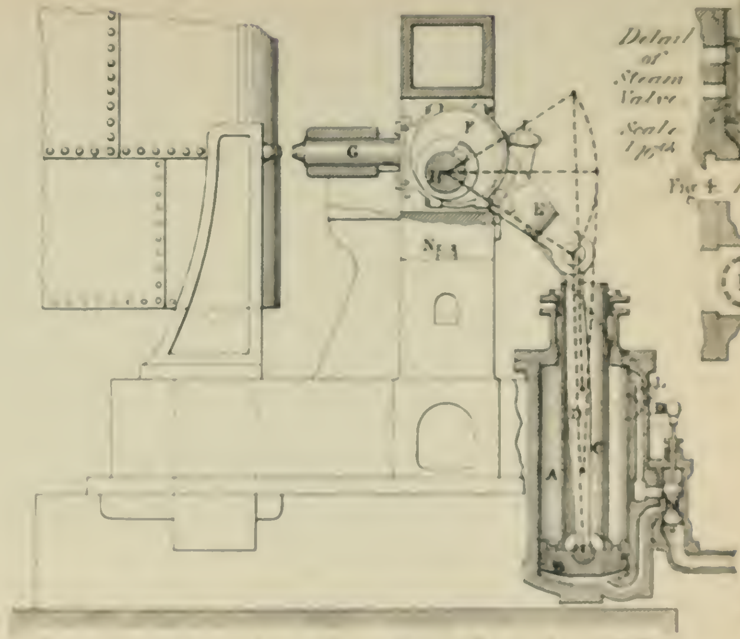


Fig. 2. *Longitudinal Section.*

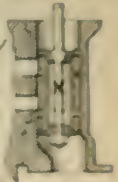


Fig. 3. *Section*

Detail of Steam Valve

Scale 1/16th

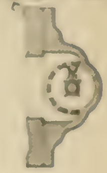


Fig. 4. *Plan*

Scale 1/32nd *Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet*

(Proceedings Inst. M. E. 1856 Page 134)

Plate 66.

CORN MILL MACHINERY

Fig 1 *Vertical Section of New Corn Mill Machinery*

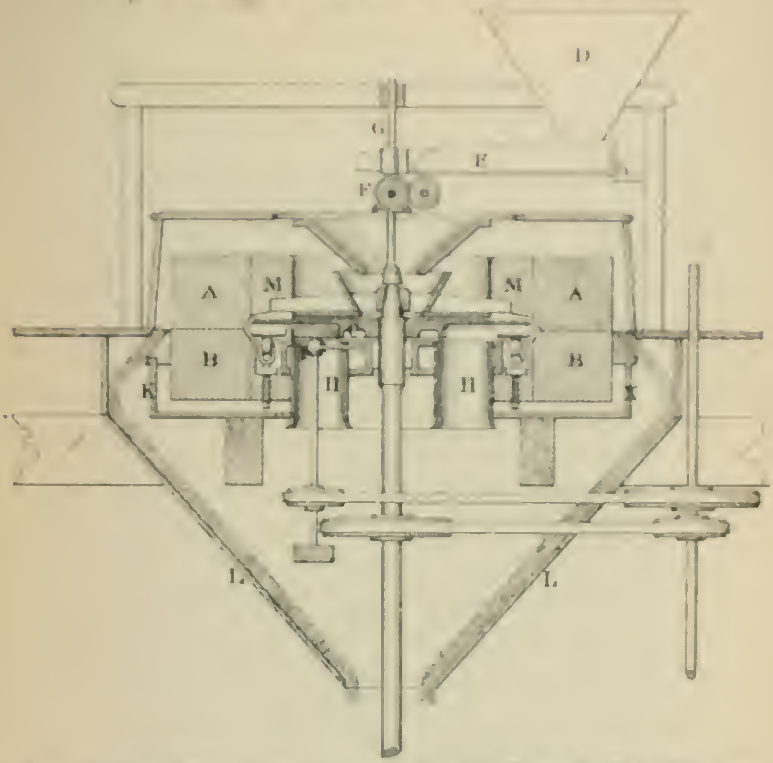


Fig 2 *Sectional Plan*

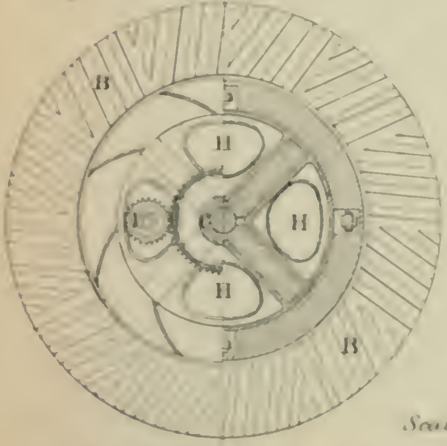
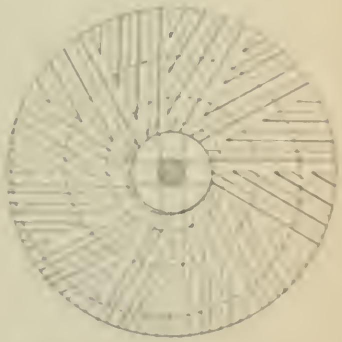


Fig. 3 *Plan of Old Millstone*



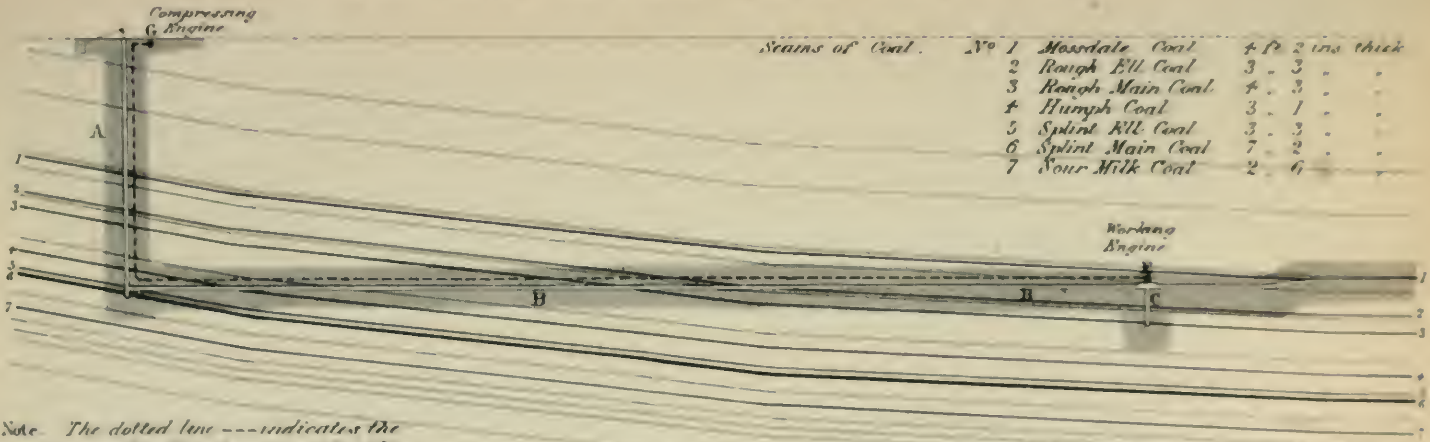
Scale $1/32^{nd}$

Inches 12 6 0 1 2 3 4 5 6 Feet

(Proceedings Inst M E 1856 Page 140)

COMPRESSED AIR ENGINE.

Fig. 1. *General Section of Govan Colliery showing the course of the Compressed Air Main through the Workings.*

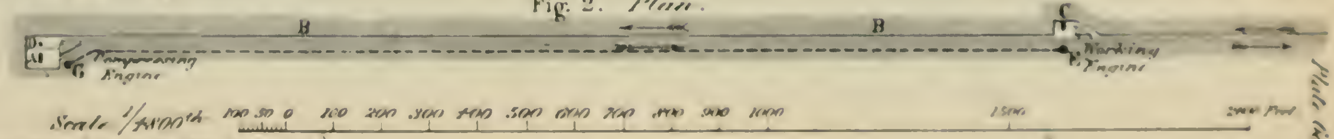


Seams of Coal.

No		ft	ins	
1	Mossdale Coal	4	2	thick
2	Rough Ell Coal	3	3	"
3	Rough Main Coal	4	3	"
4	Humph Coal	3	1	"
5	Splint Ell Coal	3	3	"
6	Splint Main Coal	7	2	"
7	Sour Milk Coal	2	6	"

Note. The dotted line --- indicates the course of the 10 inch main, of 2650 feet total length, conveying the compressed air from the compressing engine G to the working engine E.

Fig. 2. *Plan.*


B
B
C
D
A
G Compressing Engine
E Working Engine
100 50 0 100 200 300 400 500 600 700 800 900 1000 1500 2000 Feet

Scale 1/4800th

(Proceedings Inst. M. E. 1856 Page 145.)

COMPRESSED AIR ENGINE.

Fig. 3. *Enlarged Section of Govan Colliery.*
showing the position of the Compressed Air Main.

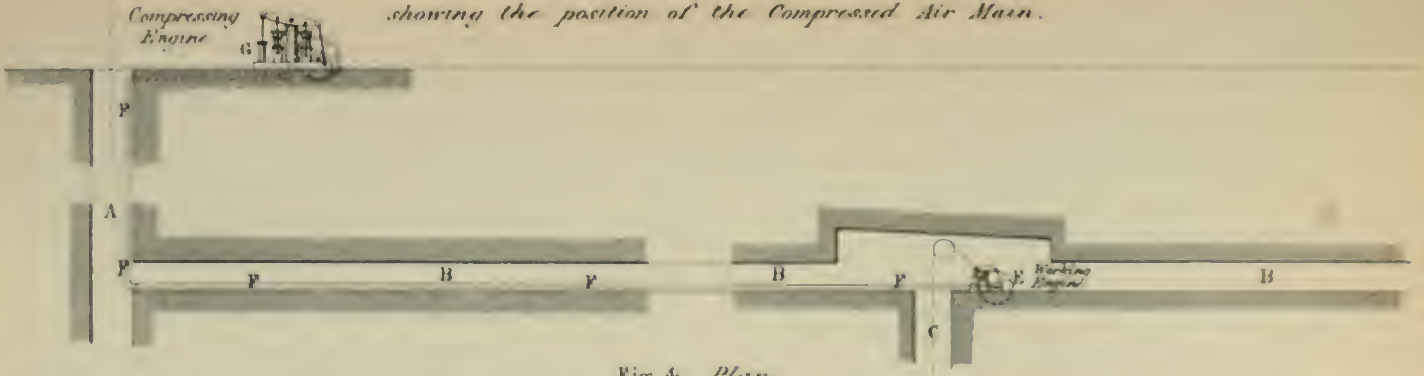
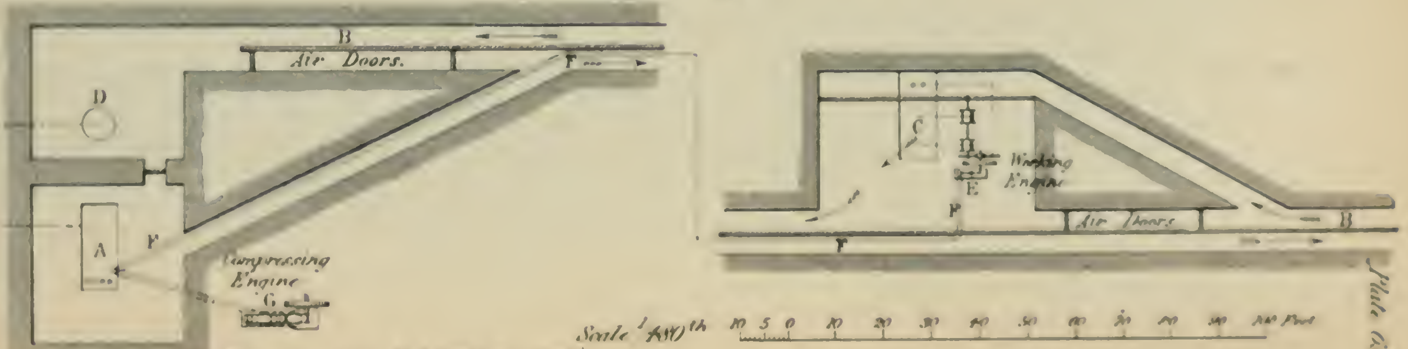


Fig. 4. *Plan.*



(Proceedings Inst. M.E. 1856. Page 145.)

COMPRESSED AIR ENGINE.

Fig 5. Vertical Section of Compressed Air Engine at Govan Colliery.

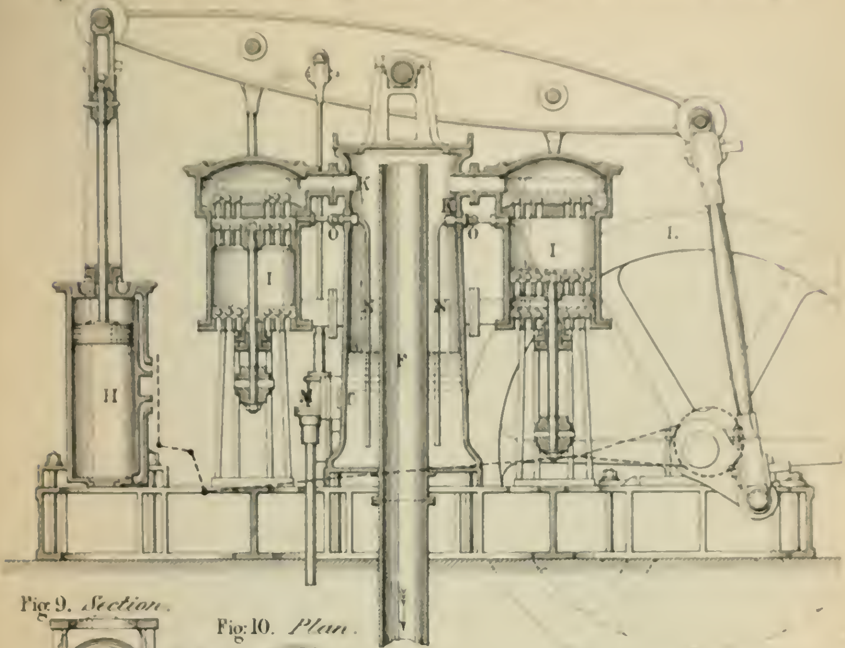
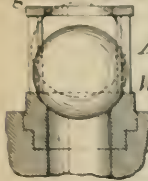


Fig 9. Section.



Detail of Valves.

Scale 1/4th

Fig: 10. Plan.

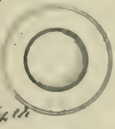
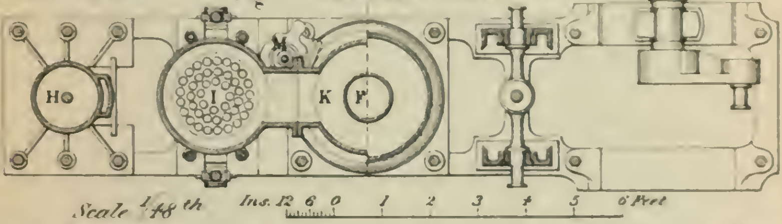


Fig: 6. Sectional Plan.



Scale 1/48th Ins. 12 6 0 1 2 3 4 5 6 Feet

Fig: 7. Vertical Section of Air Pump

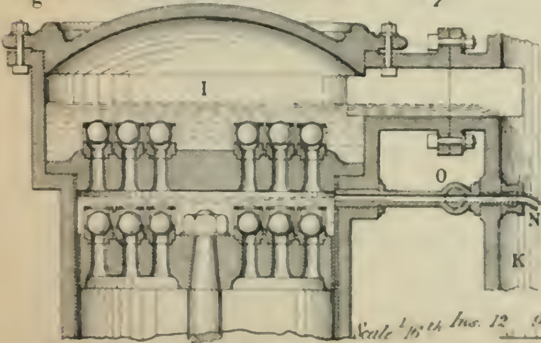
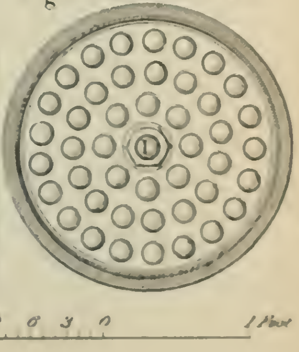


Fig. 8. Sectional Plan.



Scale 1/16th Ins. 12 9 6 3 0 1 Foot

(Proceedings Inst. M. E. 1856. Page 146.)

PISTON WATER METER.

Fig. 1 *Side Elevation with Cylinder in Section*

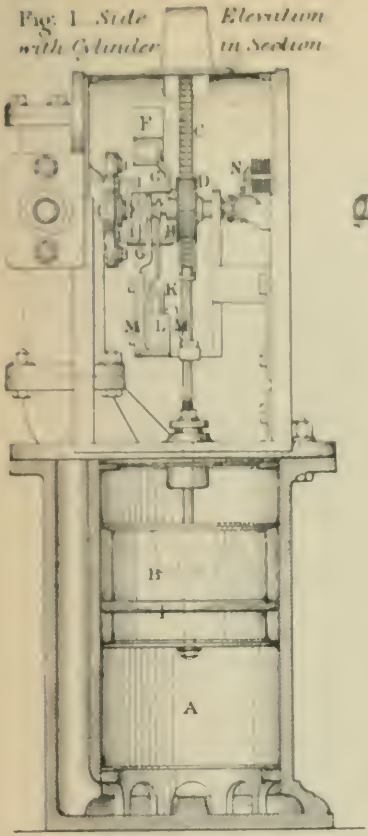


Fig. 2 *Vertical Section*

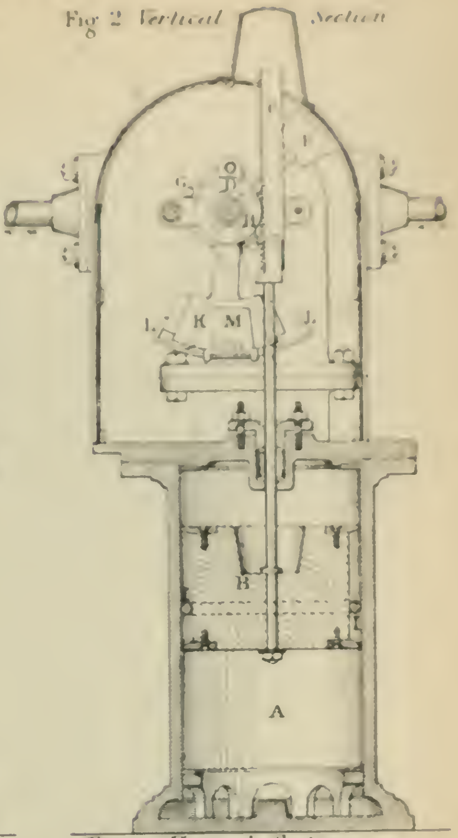


Fig. 3 *Plan.*

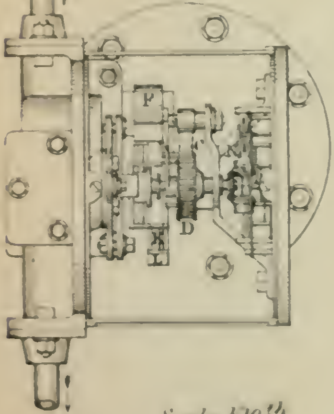


Fig. 4 *Vertical Section through inlet and outlet pipes*

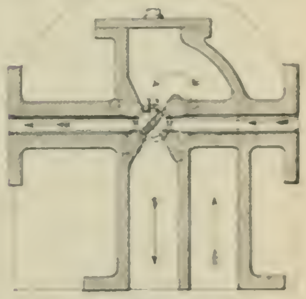
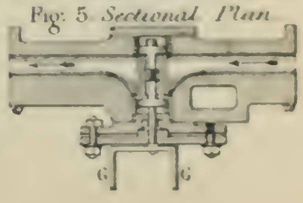


Fig. 5 *Sectional Plan*



Scale 1/10th

0 3 6 9 12 Inches

(Proceedings Inst. M.E. 1856. Page 153.)

PROCEEDINGS.

SEPTEMBER 17 AND 18, 1856.

The SPECIAL GENERAL MEETING of the Members was held in the Scottish Exhibition Rooms, Bath Street, Glasgow, on Wednesday, September 17th, 1856; JOSEPH WHITWORTH, ESQ., President, in the Chair.

The SECRETARY read the Minutes of the last General Meeting, which were confirmed.

The PRESIDENT then delivered the following opening address:—

ADDRESS OF THE PRESIDENT.

Gentlemen,—This being the first time I have taken the chair since you did me the honour to elect me your President for the present year, I propose to address you shortly on a few topics more or less connected with our profession of mechanical engineering. But first, let me express my gratification, and I am sure that of my fellow-countrymen, in thus meeting our northern friends in this important city of the mechanical arts. Formerly it was said of the Scotch mechanic, that, once south, he never crossed the Tweed a second time; but the science with which we are so immediately connected has so shortened time and distance, that these circumstances are changed; for now he no longer has occasion to bid good bye to his native land, but, thanks to railways, the penny post, and the electric telegraph, can keep up his family connections, and return occasionally to see those who are dear to him, and to enjoy the scenes of his early recollections.

The city of Glasgow is peculiarly interested in the mechanical arts, for the minerals for making iron are found in great abundance in this locality; indeed it is to this neighbourhood, more than to any other, that the world is indebted for the cheapest and most abundant supply of iron. Here, too, that metal is converted into a great variety of machinery. There are large manufactories of the steam engine—fixed, marine, and locomotive. Cotton manufacturing and various other kinds of machinery are also made here in considerable quantities. With such links of connection amongst us, I trust that this, our first meeting in this city, may be the forerunner of many others, and that we shall add many valuable members to our Institution.

With regard to the manufacture of malleable iron and steel, it was with great gratification that I read the account of Mr. Bessemer's invention, so beautiful and simple as apparently to leave nothing further to be desired in that part of the process. I need not tell you of what vast importance it must be to those who are more immediately connected with those branches of mechanics requiring nicety of workmanship, to have iron and steel of a better quality. I may mention that in making rifle barrels for the experiments which I have undertaken for the Government, one of the greatest difficulties I encounter, in attaining the degree of accuracy that I require, arises from the defects in the iron. What we want is iron of great strength, free from seams, flaws, and hard places. Inferior iron (with the use of other defective and improper materials) is perhaps the main cause of one of the greatest errors committed in the construction of whatever in mechanism has to be kept in motion. I mean the increase of size of the parts of a machine or carriage, in order to get strength, thereby adding weight until they are considered to be strong enough. In our vehicles of draught and carriages this is strikingly the case. Now this ought not to be. Lightness is the thing to aim at, and safety should be sought in the elasticity, form, and good quality of the material. Should a carriage be found to twist and get out of form, that would be a proof of its being too light. But to prevent a carriage breaking down by increasing the size of its parts, and thereby adding weight, is mechanically wrong.

Indeed it is quite distressing to see the enormous weight of our carriages, particularly those drawn by animal power. It should be an axiom in mechanics, that whatever has motion should be as light as circumstances will admit; and this applies equally, whatever the source of power may be, whether the motion is produced by human, horse, or steam power.

I would next call your special attention to the vast importance of attending to the two great elements in constructive mechanics,—namely, *a true plane* and *the power of measurement*. The latter cannot be attained without the former, which is therefore of primary importance; and its accomplishment is so easy and so simple as to leave without excuse any establishment neglecting to secure it. It is necessary to make three planes in order to obtain a perfect one, and cast iron is the best material generally to use. Whatever the size of the plane required, the tripod form is absolutely essential for its support; and the strengthening ribs must be placed with reference to the supports. I cannot impress too strongly on the members of the Institution, and upon all in any way connected with mechanism, the vast importance of possessing a true plane, as a standard for reference. All excellence in workmanship depends upon it. I may mention that it was at the meeting of the British Association held in Glasgow in 1840 that I read a paper on the mode of producing a true plane, to which I would refer those desiring information on the subject.

Next in importance to a true plane is the power of measurement. I have brought with me, for your inspection at the close of the meeting, a small machine, by which a difference in length of the one-millionth part of an inch is at once detected. The principle is that of employing the sense of touch, instead of sight. If any object be placed between two parallel true planes, adjusted so that the hand can just feel them in contact, you will find, on moving the planes only the 50-thousandth of an inch nearer together, that the object is distinctly tighter, requiring greater force to move it between them. In the machine before you, the object to be measured is the standard inch, in the form of a small square bar, both ends being true planes; and in this case, in order to measure with the utmost accuracy, a thin flat piece or bar is introduced, having its two sides made also perfect planes. This is placed between the inch bar to be measured and one of the end surfaces of the machine. This thin bar, which I name the gravity piece, is brought into contact with the two planes, so as just to allow it, on being raised, to fall by its gravity; and you will find that, by bringing the planes into closer contact by even the one-millionth of an inch, the gravity piece will be suspended, friction overcoming its gravity. This machine, and a larger one, are used for making standards of length. When the standard yard, which is a square bar of steel, is placed in the larger machine, and the gravity piece adjusted so as just to fall by its weight, the heat imparted from the slightest touch of the finger instantly prevents its fall, thus showing the lengthening of the bar by so small an amount of heat as that I have indicated. We have therefore in this mode of measurement all the accuracy we can desire; and we find in practice in the workshop that it is easier to work to the ten-thousandth of an inch from standards of end measure, than to the one-hundredth of an inch from the lines on a two-foot rule. In all cases of fitting, end measures of length should be used, instead of lines.

This question of correct measurement is in immediate connexion with another, which will repay all the attention that can be given to it, and I think there is no subject that can be more profitably discussed amongst us;—I mean that of *proper gradations of size* in all the various branches of the mechanical arts. I think no estimate can be formed of our national loss from the over-multiplication of sizes. Take for instance the various sizes of steam engines—stationary, marine, and locomotive. In the case of marine engines, the number of sizes up to 100 horse power will probably not be short of thirty, where ten perhaps would be ample. If so, look at the sums expended in patterns, designs, and in the number of tools for their manufacture. Nor is this all; for if there were only ten sizes instead of thirty, there would be three times the number made of each pattern; and, as you know, the very soul of manufacture is repetition. By attention to this, the shipowner would be benefited by getting a better engine at a less price. In the case of locomotives and carriages, I would urge the subject on the attention of our members, the engineers of the great lines of railway—the London and North Western, the Midland, the Great Northern, for instance. I hope they will permit me to suggest that they should consider and determine not only the fewest possible number of sizes of engines and carriages that will suffice, but also how every single piece may have strictly defined dimensions. This question is also well worthy the attention of our architects and builders. Suppose, for instance, that the principal windows and doors of our houses were made only of three or four different sizes. Then we should have a manufactory start up for making doors, without reference to any particular house or builder. They would be kept in stock, and made with the best machinery and contrivances for that particular branch; consequently, we should have better doors and windows at the least possible cost. Our friends across the Atlantic manage matters in connexion with their buildings much better than at present we do.

I hope the members of this Institution will join me in doing what we can with reference to those two important subjects—correct measurement, and its corollary, proper gradations of size. The want of more correct measurement seems to pervade everything. Take for instance the case of the common brick, which ought to be three inches thick. Who is there that has made an addition to a building who has not felt inconvenience from the irregularity of size?—the new brick being perhaps too thick, and so not allowing sufficient mortar to be used; or too thin, and requiring too much mortar.

Perhaps one of the most effectual means that could be adopted, in the first instance, to remedy this unsatisfactory state of things, would be for the Government to supply corporate bodies with proper standards of length—such as the inch, the foot, and the yard. The corporate bodies themselves might then have their own standards of size, founded on these, and made to suit the particular wants of the different trades in the locality. The only standard of length at present supplied by the Government and kept by the corporate bodies is the standard yard, but there is so little attention paid to accuracy, that to the engineer and machinist it is not of the slightest use, and is only employed to adjust yard sticks for measuring woven goods.

There is also another subject which bears upon this question, and which has lately been brought before the Legislature—that of decimalising weights and measures. There can be no doubt of the beneficial results that would follow the passing of such a measure. There may be a difference of opinion as to what the unit or integer of lineal measure should be; but I am of opinion that it should be the inch, for, from the accuracy with which we can now measure that length, there would be no difficulty in determining and fixing the length of its multiples. The most important divisions of length in mechanism are those of parts of an inch, and if the length of the inch were altered it would cause much confusion. Small accurate standards of length, of the decimal parts of an inch, would be of much service to some trades. There is now no standard of appeal; and the different wire and other gauges differ so considerably, that the manufacturer, in the case of small wire and sheets of metal, has to send a sample of what he wants, there being no means of correctly expressing its size.

Although I have said so much to you with reference to the desirableness of farther improvement and greater perfection in the mechanical arts, I congratulate you on the success which in our time they have attained, and the high consideration in which they are held. Inventors are not now persecuted as formerly by those who fancied that their inventions and discoveries were prejudicial to the general interest, and calculated to deprive labour of its fair reward. Some of us are old enough to remember the hostility manifested to the working of the power-loom, the self-acting mule, the machinery for shearing woollen cloth, the thrashing machine, and many others. Now, the introduction of the reaping and mowing machine and other improved agricultural machinery is not opposed. Indeed it must be obvious to reflecting minds that the increased luxuries and comforts which all more or less enjoy are derived from the numerous recent mechanical appliances and the production of our manufactories. That of our cotton has increased during the last few years in a wonderful degree. In 1824, a gentleman with whom I am acquainted sold on one occasion one hundred thousand pieces of 74 reed printing cloth at 30s. 6d. per piece of 29 yards long; the same description of cloth he sold last week at 3s. 9d. One of the most striking instances I know of the vast superiority of machinery over simple instruments used by the hand is in the manufacture of lace, where one man with a machine does the work of 8000 lacemakers on the cushion. In spinning fine numbers of yarn, a workman on a self-acting mule will do the work of 3000 hand spinners with the distaff and spindle; and there are other striking facts of a similar kind mentioned in my report on the New York Industrial Exhibition.

Comparatively few persons, perhaps, are aware of the increase of production during our lifetime. Thirty years ago, the cost of labour for trueing a surface of cast iron, by chipping and filing with the hand, was 12s. per square foot; the same work is now done by the planing machine at a cost for labour of less than 1d. per square foot, and this, as you know, is one of the most important operations in mechanics. It is therefore well adapted to illustrate what our progress has been. At the same time that this increased production is taking place, the fixed capital of the country is, as a necessary consequence, augmented; for, in the case I have mentioned of chipping and filing by the hand, when the cost of labour was 12s. per foot, the capital required for tools for one workman was only a few shillings; but now the labour being lowered to 1d. per foot, a capital in planing machines for the workman is required, which often amounts to £500, and in some cases more. This large outlay of capital, invested in machinery to increase production, makes it impossible to curtail the hours of working machinery as much as could be desired. In some cases two sets of workpeople have been employed in relays, each working eight hours a day; and this system perhaps may in time be extended, although it is attended with certain inconveniences. If however the relay system could be so improved and organised as to allow more time for the better education of young operatives, none would more cordially rejoice than myself. I believe that mechanics, though a mere material power in itself, may, if rightly used, become a moral lever, by which, like Archimedes of old, we may seek to raise the world.

There is at the present time a very gratifying circumstance in connexion with the extension of machinery; namely, the large remuneration which the operatives receive compared with those who perform hand labour without the help of machinery. I would here mention, with reference to the amount of wages paid to the operative, that it does not depend solely on the master manufacturers of this country, but is governed in some measure by what is paid by the manufacturers of other countries who are in competition with our own. When in America in 1853, I found that the American operatives received somewhat more wages than are paid in this country; but they worked much longer hours, although the climate, during some parts of the year, is so unfavourable. These longer hours enable the American manufacturer to turn over his capital more frequently.

This question of increased production, with which we, as mechanical engineers, are so identified, is so entirely dependent on the power of the people to consume, that I hope I shall be excused in adverting to it. Our yearly exports now amount to about a hundred millions sterling, having doubled in a short time, while our home productions have been greatly increased from the same cause, namely, the increased ability of our people to consume. As a general principle it would seem to be far better to levy a small impost on the entire wealth of an individual rather than to fasten a tax on particular objects, which if produced would constitute wealth, but which are not made because of the threatened impost. The remaining duty on carriages seems to me to be one of this description. Were there no tax, almost every one who keeps one carriage would keep more, while large numbers would have one who now have none. By their use locomotion would be increased threefold, and hence much valuable time would be saved. Besides, what a number of the best description of artisans would be called into existence for their manufacture—a class, too, who are well able to turn their hand, in cases of necessity, to other employment. If therefore it is desirable for a nation to possess wealth in carriages, it is a mistake for legislation to prevent it.

Formerly, when the wealth of a nation was produced as it were by hand labour, a different state of things existed to that of the present day. As I have shown, our means of production are now increased in some cases more than a hundred, and in others more than a thousand fold; and this will go on just in proportion as the masses of our people are able to consume larger quantities of everything that they require. When the farm labourer pays less for his sugar and tea, more meat will be consumed (which again goes to improve the land); also more wool for our manufactures.

In this wonderful power of producing wealth which now exists, none can be more interested and benefited than the proprietors of the land. A striking proof of this is given by its increased value in the manufacturing counties, and for miles adjoining our manufacturing towns. The competition too of our manufacturers and merchants to become possessors of land is shown by the small rate of interest with which they are satisfied for the outlay of their capital on the soil. The proprietors of land may rest assured that, in the future development of mechanical improvements, none will be more benefited than themselves. I do not hesitate to say that all harvest operations on land properly laid down will very shortly be performed in one-fourth the time required with the hand labour now expended, by the farther application of machines worked by horse power. This is my conviction, based upon the experience I have had in the successful working of the machine I constructed for sweeping the streets, and at the same time filling the cart, by horse power. By the combined aid of mechanical improvements and the science of chemistry, together with the greater skill of our modern agriculturists, the culture of the land throughout Great Britain must more and more approximate to that of a garden.

We have seen the effect of the repeal of the duties on glass and bricks, in the improved appearance and reduced cost of residences, and a still further benefit may be expected to result from the removal of the remaining duty on timber. While therefore we congratulate ourselves on the great results which the mechanical arts have achieved, we have every reason to be thankful that our legislators have removed so many impediments to our progress. The glorious fruits of the legislative labours of that great and good man, Sir R. Peel, may give us hope that the time is not far distant when all remaining obstacles of this kind will be swept away. When that period has arrived, and when the industry of this country has been systematised upon sound principles of economical science, and in each department carried nearer to those standards which, in the case of mechanics, I have endeavoured to indicate, we shall have less reason than at present to doubt the stability of our manufacturing pre-eminence.

Mr. FAIRBAIRN moved a vote of thanks to the President for his able and appropriate address, which was passed.

The following Paper, by Mr. Robert Harvey, of Glasgow, was then read:—

DESCRIPTION OF AN IMPROVED STEAM RIVETTING, PUNCHING AND SHEARING MACHINE.

In the manufacture of steam boilers, the operation of rivetting is mostly effected by hand labour, and in order to bring the heads of the rivets to a proper form and finish, much of the hammering takes place when the rivet has approached to a nearly cold state, the tendency of which is to destroy to a certain extent the fibrous character of the rivet. The case of a rivet head starting off under the operation of proving the boiler, although seldom occurring, has revealed the fact that a crystalline character must be more or less assumed by the iron in all rivets worked in the usual manner; and hence, besides aiming at economy by the use of steam for rivetting, it is very desirable that the rivets should be finished in as short a time as possible, and without that succession of blows by which the fibrous character of iron is always more or less injured.

Steam rivetting machines are not a recent invention; they have been tried and abandoned in some cases, from their complexity and liability to derangement. Other machines, in which a cam moved through a fixed distance, acting through a combination of levers, having always a fixed distance for the travel of the rivetting die, have lost favour from being unable to adapt themselves to irregularities in the lengths of rivets, which must of necessity occur at the junction of plates, where "three plies" are used, and in the general work, when the rivets are not absolutely correct in length. In other steam rivetting machines that are called direct-acting, which have deservedly been well received, a very high pressure of steam, 50 lbs. per square inch, is used, requiring in most cases a separate boiler for the machine, or a greatly increased size of steam cylinder, and consequent augmentation of price.

In the machine now described, the joint invention of the late Mr. Whitelaw and the author, and manufactured under the author's immediate superintendence, the three essential processes of boiler making,—punching, shearing, and rivetting—are effected by one steam cylinder, and in one frame.

The machine is shown in Figs. 1 and 2, Plate 66.

Fig. 1 is an end elevation of the machine, and Fig. 2 a longitudinal section through the steam cylinder.

The steam cylinder A, Fig. 2, is 15 inches diameter, and has a stroke of 24 inches; the piston B has a trunk C attached to it, by means of which the piston rod D has room to accommodate itself to the travel of the radiating lever E, to which it is attached by a strong pin joint. This lever has an eye F forming an eccentric, to which the slide G carrying the rivetting die is attached by a strap of considerable breadth, so that the whole working pressure may be distributed over a surface of great extent; consequently in the present machine, after nearly twelve months' constant work, no perceptible wear is exhibited.

The wrought iron shaft H, upon which the lever E is securely keyed, is 6½ inches diameter, and works in long and truly bored bearings in the frame. One end of the shaft works the punching slider I by a pin turned eccentrically so as to give the necessary travel; the other end works the shearing slider K in a similar manner. The shears and punch travel 1¼ inch, and the rivetting die about 3 inches.

It has not been thought advisable to render the machine entirely self-acting; it is started and stopped by hand for every stroke performed. The steam is used only during the "up" or effective stroke, the weight of the piston, trunk and radiating lever being sufficient to bring the piston to the bottom of the cylinder. Between the bottom of the cylinder and the piston, a portion of the exhaust steam is retained as a cushion, by which the piston and all the parts connected with it are softly brought to rest; this is effected by a self-acting arrangement of levers L, in connection with the eye F of the radiating lever.

The steam used in this machine is not more than 20 lbs. per square inch pressure; but through the intervention of the lever arm the power is sufficient to punch a ¾ inch hole through a ¾ inch plate. The steam valve M, Figs. 3 and 4, is an equilibrium valve, consisting of a double piston with metallic packing, the steam being admitted to press upon each end of the valve, and the discharged steam passing out round the centre; being perfectly balanced, this valve is moved at each stroke with the greatest ease and accuracy.

In punching, the plate is moved along the bolster N till the mark is in the proper position; the steam valve is then slightly lifted, and the hole is instantly punched with a very small expenditure of steam. The steam is shut off the moment the punch is seen to strike the plate, a sufficient quantity of steam having been by that time admitted to complete the work; the resistance of punching the hole and the weight of the piston and lever overcome the force of the steam when about two-thirds of the stroke has been performed, and the piston then returns to the bottom of the cylinder, ready for the next stroke, the time for which is seen by the man in charge of the machine, and the stroke is effected at the instant required. A great economy of time arises from the circumstance that the punch is not limited to a fixed number of strokes per minute, but can be worked at any rate that may be required to suit accidental variations in the work. The time in which work can be done is limited only by the men working the machine. Thirty $\frac{11}{16}$ inch holes can be punched in a $\frac{7}{16}$ inch plate in one minute, and in rivetting 8 to 10 rivets can be put in in the same time.

A decided advantage is obtained in this machine by the eccentric motion employed to move the rivetting ram; for as the full side of the eccentric approaches its extreme point in the centre of the ram, a continually increasing power is obtained, the greatest power being in action when the rivet is being finished, and the plates by this means are drawn into the closest contact.

The boiler work to be rivetted is suspended in the position shown in Fig. 1, from a strong frame of simple construction, carried by two upright standards, which rest upon knuckle joints at the bottom; the standards are capable of complete adjustment by means of two horizontal beams, having their ends attached near to the top of the standards, and passing through a wall, with racks upon their other ends gearing into pinions; by turning these pinions the top of the frame carrying the work is adjusted, and brought into the required position with respect to the stationary die.

The CHAIRMAN said that the strangers present were invited to take part in the discussion on the papers that were read, and the meeting would be glad to hear their observations, and hoped to receive the benefit of their opinion and practical experience.

He thought the rivetting machine described in the paper that had just been read was well worthy of attention, and enquired how many of the machines were at work.

Mr. HARVEY replied that only one machine of the kind had yet been constructed, which was at Mr. Cook's works in Glasgow, where it had been working satisfactorily for nearly 12 months, and had been found a very useful and advantageous tool. He exhibited a specimen of two plates rivetted together by the machine, and planed down to the centre of the rivets, in order to show the perfection of the work.

Mr. FAIRBAIRN considered there was a great advantage in machine rivetting over hand rivetting; the machine rivets were finished whilst hot, and the contraction in cooling was sufficient to render the joint perfectly steam or water tight. Great economy of time was also effected by the machine, as twelve rivets might be closed and finished by the machine in the time required to finish one rivet by the hammer. In the original rivetting machine, provision was made for different lengths of rivets and different thicknesses of plates, by means of a wedge behind the die, which was drawn up or lowered down by a screw, so as to adjust the rivetting die to a variable length of stroke. He found that the pressure required to form a rivet head amounted to 5 tons, which had a great tendency to break off the standard or stem of the machine; and in one machine three stems had been broken in sixteen years, although of great strength, affording an interesting illustration of the strength of materials when subjected to a long series of changes in the molecular construction; even a wrought iron stem 8 or 10 inches diameter had been broken. In the direct-acting steam rivetting machines however the strain upon the machine could never exceed the amount of pressure originally designed for completing the rivet. He believed that one of the earliest applications of power to rivetting had been made by himself, and the earliest plan comprised only a lever acted on by a cam, in a manner somewhat similar to that now described, but without the advantage of the variable length of stroke given by the steam piston, which he considered a valuable improvement. The machine now described presented a beautiful and excellent combination of the two principles on which the success of steam rivetting depended,—a variable length of stroke of the rivetting die, and sufficient rapidity of execution to complete the rivet while hot; and the addition of the punching and shearing apparatus made it a very complete tool.

Mr. Harvey observed that a pressure of 5 tons had been mentioned as necessary to form the rivet head; but in the present machine 30 tons pressure was obtained at the end of the stroke, in consequence of the proportion of the lever and eccentric, the advance of the die at the end of the stroke being at only one third of the rate at the commencement. As the result of this heavy pressure, a considerable difference was found in the rivets put in by this machine compared with those put in by ordinary direct-acting steam rivetting machines, the heads in the latter case being round and open at the edge, whilst those made by the present machine were quite close and finished all round, in consequence of the great nip given by the die in finishing the rivet. The rapidity of the work with this machine was so great that three rivets put in by it would remain still red at once. In proving boilers a slight leakage was found where the rivets had been put in by hand, but none at all where they had been put in by the machine. The only accident that had occurred with the machine since starting had been a breakage of the frame bed, which consisted of four metal webs 16 inches deep by 4 inches thick; these were broken asunder a few weeks after starting, and six 2½ inch Low Moor bolts were then put in to secure the fracture, and they were found quite successful; there was still however a very slight yielding by the opening of the joint at the end of each stroke, but this perhaps saved the frame from a further breakage, by the slight elasticity that was allowed.

Mr. Fairbairn remarked that Messrs. Stephenson, of Newcastle, had a rivetting machine, in which the rivets were made by the same machine. It was worked by an eccentric which lifted a knuckle or elbow joint, as in an ordinary printing press, giving an action similar to that in the machine that had been described, the pressure increasing towards the completion of the stroke; the projection of the die was adjusted to the thickness of the plates, and this plan had been found satisfactory. Machine rivetting was undoubtedly superior to that done by hand, and he hoped it would soon be still further improved by the introduction of portable machines.

Mr. FOTHERGILL observed that the conical form of head in hand rivetting, arising from the mode of striking with the hammers, was inferior in strength and substance to the round headed machine rivet; this was a point that was not always recognised, and he had known cases where a hand rivetted boiler had been thought stronger, because neater in the appearance of the rivets, but was found on trial inferior in tightness to a machine rivetted boiler.

Mr. RAMSBOTTOM asked what means were adopted to prevent the plunger striking the end of the cylinder in the new machine, when the resistance was suddenly removed in punching a plate.

Mr. HARVEY replied that the machine was regulated by hand without difficulty; as soon as the man saw the punch strike the plate, he then suddenly shut off the steam, enough having been by that time admitted to complete the punching of the hole; the power of the steam was thus spent, and the lever returned immediately to its original position ready for the next stroke. A wood block was at first fixed on the frame as a buffer to stop the lever before the plunger reached the top of the cylinder; but this was not now found necessary, as the steam was allowed to escape by a side passage into the exhaust pipe before a blow on the frame could take place.

The CHAIRMAN moved a vote of thanks to Mr. Harvey for his paper, which was passed.

The following Paper, by Mr. Alexander White, of Partick, was then read:—

DESCRIPTION OF IMPROVED CORN MILL MACHINERY.

In the ordinary mode of grinding wheat, the grain after being properly cleaned is placed in a hopper above the millstones, and is thence fed in a regular manner into the eye or central aperture of the running or top stone, and by the centrifugal effect of the stone's rotation is carried round in a spiral direction between the two stones, until it gradually reaches the circumference of the stones, whence it issues in a ground state and passes down a spout into a bin below. In this system, which has been in use for a few centuries past, there is, the writer thinks, ample room for improvements, involving both an increase in the speed of production, and superior quality of the flour.

There is an injurious effect exercised upon the grain by coming in contact with the central portion of the stones, as at that part it is tortured over and over on a sharp flinty surface of nearly five feet area, and with a motion which, being insufficient to grind it, tears the husk and kernel to the detriment of the flour; this action taking place before the grain reaches that portion of the stones where there is motion at once sufficient to grind it and to discharge the ground particles from between the stones.

In the improved arrangement of corn mill machinery, forming the subject of the present paper, the area at the centre of the stones, which in ordinary millstones acts so injuriously upon the grain, is altogether removed, the stones being cut away at that part; whilst in the opening there is inserted a large distributing disc, which is driven at a high speed for the purpose of delivering the prepared grain between the stones and also causing a current of air as afterwards described.

The new corn mill machinery is shown in Plate 67.

Fig. 1 is a vertical section of the improved arrangement of millstones.

Fig. 2 is a plan of the lower millstone on the new construction, showing the air fan in horizontal section, the distributing disc being removed.

Fig. 3 is a plan of a millstone as constructed on the old system; the dotted line shows the spiral path of a grain of corn, on its way from the centre, where it is delivered between the stones, to the circumference, where it is discharged in the ground state.

A, Fig. 1, is the top or running stone, 6 feet diameter, and B the bottom stone which remains stationary. The centre portion of each stone is cut away, leaving a hole or eye 2 feet 9 inches diameter, in which is inserted the distributing disc C for delivering the prepared grain between the stones. The grain is supplied from the hopper D along the spout E. A small crushing apparatus F is placed above the stones, consisting of a pair of rollers driven from the damsel spindle G by means of bevil wheels; the grain passes between the rollers on its way to the grinding surfaces, being bruised or crushed by the rollers, which greatly facilitates the grinding process, and improves the quality of the flour. The crushed grain from the rollers falls upon the distributor C, the surface of which is corrugated or notched radially, to aid the distribution of the rolled grain; the distributor is recessed half way into the face of each stone and revolves clear of the lower stationary stone B, and also of the running stone A.

The distributor C is constructed so as to serve the double purpose of delivering the grain between the stones, and also of supplying a current of cool air along with the grain. The distributing disc, on which the crushed grain falls, forms the upper side of a horizontal fan, which discharges a current of cool air along with the grain between the stones. The air is drawn up through the enlarged eye of the bedstone B, which instead of being entirely closed up as formerly, is left open, like the eye of the running stone A, to allow of the free introduction of cool air to act upon the grain where the grinding action comes into most effective play. The fan is made with a number of curved arms, as shown in the sectional plan, Fig. 2, the spaces between them forming horizontal curved passages for the air; the outer ends of the air passages terminate at the circumference of the distributor, and the inner ends open into the central chamber of the fan, which communicates at the under side with the trumpet-mouthed air tubes H H, which pass out through the eye of the lower stone B, and are thus capable of taking in cool air from below.

The action of the fan is such that as the upper stone revolves a current of cool air is drawn up through the tubes H, and discharged in a powerful stream upon the grain being ground, just at the part where the grinding process comes into effective operation. By these means the grinding is accomplished very rapidly and well, and the grain and flour are kept quite cool and in good order. If the simple rate of the stones does not produce a sufficient current of air by means of the fan, as may be the case with stones of large diameter, the fan is driven at a greater velocity than that of the stones, by means of gearing I, and is arranged to revolve freely about the mill spindle.

A further improvement is effected in the discharge of the flour from the millstones. Instead of allowing the flour to be carried round the inside of the casing K, so as to be delivered down a spout placed at one side, the casing is formed with openings almost all round it, through which the flour falls in a thin film into the conical or funnel-shaped casing L below. In passing down this casing the flour is exposed to the beneficial action of the upward current of cool air, which is ascending to supply the fan, the heated air passing off by the ordinary opening in the case over the top of the running stone. When the flour leaves the casing L by a spout at the bottom, it is in a perfectly cool state, and may be immediately bolted and put up into sacks for the baker.

The present improvements may be applied to a certain extent to old stones; but in erecting new mills or machinery the stones should be made considerably larger than hitherto; that is to say, they should be at least 6 feet in diameter, instead of only 4 feet or 4 feet 6 inches. These large stones should be composed of a ring of burr blocks 1 foot broad, as shown in Figs. 1 and 2, built up and nicely joined round a centre ring or rim M, composed either of a single piece of free-stone, or of cast iron.

Stones fitted up with the various improvements above described have in practice been found to do double and in some cases more than double the work done by ordinary stones, whilst the flour produced has been of greatly superior quality; and where the larger size of stones can be got, still better results will be obtained, whilst the motion will be easier, and there will be less of the tremor and vibration which with ordinary arrangements frequently annoys and frustrates the expectations of the most careful miller.

Mr. Dunn asked whether the stones were driven at the same speed as in ordinary grinding.

Mr. White replied that they were driven at present at the same rate as the ordinary stones, about 110 revolutions per minute for the $4\frac{1}{2}$ feet stones; but it was intended to increase the speed, as they might be driven considerably faster without heating the flour.

The Chairman enquired how many pairs of stones were at work on the new plan.

Mr. White said he had only two pairs at work at present, which had been altered from the old construction, and had been working eight months with such satisfactory results that it was intended to extend the application of the plan.

Mr. Fairbairn asked how much wheat per hour was ground by the new plan.

Mr. White stated that 12 bushels per hour were ground by a pair of $4\frac{1}{2}$ feet stones, which was fully double of the quantity ground by ordinary stones of the same size running at the same speed. Other plans had been brought forward for using a current of air in the operation of grinding, but still the old system of stones was generally adhered to; and he considered the alteration in the stones in the present case, reducing the grinding surface to a ring at the circumference, and substituting the air distributor in the centre, was a very important improvement in the process.

Mr. Fairbairn remarked that a great advantage was obtained in cooling the flour by the use of a current of air in grinding, and the yield had been increased by that means in some cases from 6 to 8 or 9 bushels per hour from each pair of stones. There existed however a great difference of opinion on this question among millers, some asserting that no compensating advantage was gained by the air blast, considering the power absorbed in driving the fan to be more than equivalent to the increased yield from the stones. He asked what power was required for driving the new stones, and whether they were driven by straps or gearing.

Mr. WHITE said he could judge of the power only from the water used by the wheels, but scarcely any difference was perceptible, and the saving in power from the stones not grinding in the centre probably balanced the extra quantity ground. The stones were all driven by gearing throughout the mill.

Mr. FOTHERGILL enquired whether the advantage in gain of quantity was interfered with at all by the quality of the flour obtained. The mode in which the grinding was effected was of considerable consequence, as the material of the grain was the best close to the husk, and it was therefore important to get the husk closely removed.

Mr. WHITE replied that the same quality of flour was yielded, but it had the advantage of the husk being separated with less pulverizing.

Mr. FAIRBAIRN observed that the modern plan of feeding by the silent feeder instead of the damsel was now in extensive use, and was considered superior in action by distributing the grain more equally into the eye of the stone.

Mr. WHITE said the plan of the silent feeder was a very good one, but would not admit of the application of the crushing rollers used in his arrangement.

Mr. FAIRBAIRN asked what advantage was derived from the use of the crushing rollers.

Mr. WHITE stated that he had found them to be of great advantage, in preparing the wheat and facilitating the process of grinding, especially where the wheat was of a dry and hard nature.

The CHAIRMAN proposed a vote of thanks to Mr. White for his paper, which was passed.

The following Paper, by Mr. Charles Randolph, of Glasgow, was then read:—

DESCRIPTION OF A COMPRESSED AIR ENGINE AT GOVAN COLLIERY.

The engine described in the present paper was designed for a special purpose in the working of the Govan Colliery, near Glasgow, where an ordinary engine was not applicable; and although under other circumstances not an economical mode of employing power, it has proved in the present case highly satisfactory, and has worked successfully for several years.

A general section and plan of the Govan Colliery are shown in Figs. 1 and 2, Plate 68, to a small scale.

The main shaft A is sunk 176 yards deep, through six successive seams of coal, the first of which is 92 yards from the surface at that point; and after working the coal at that part, a main road B was driven horizontally to a distance of 706 yards, intersecting the coal seams, which dip at an inclination of about 1 in 11, as shown in the drawing. A second shaft C, at present 26 yards deep, was then sunk near the extremity of the main road B, for the purpose of working the third seam, or "rough main" coal.

The difficulty then arose of providing for the winding and pumping of this second shaft at a distance of nearly half a mile from the first shaft. A steam boiler was inadmissible in that situation, and the distance was too great to convey steam from the surface. Some application of water power was contemplated by the manager, Mr. James Allan, who applied to the author for the purpose of carrying it out; and it was then proposed by the author, upon the original idea suggested by Mr. David Elder, to make use of compressed air supplied by a compressing steam engine at the surface, and conveyed down by a pipe to work an engine at the top of the second shaft in the manner of a non-condensing steam engine, the discharged air being thrown into the workings to aid in the ventilation of the mine.

This proposal was adopted, and the present engine was designed and constructed for the purpose by Messrs. Randolph, Elliot, and Co.; it has now been working at the colliery more than six years, and has been found to answer the purpose completely.

Fig. 3, Plate 69, shows an enlarged view of portions of the section Fig. 1, and Fig. 4 is a corresponding plan.

The main shaft A, Figs. 3 and 4, contains a single winding apparatus and a set of four pumps, and forms the downcast shaft for the ventilation; it is 18 feet long and 8 feet wide, being oval at the top and rectangular below. It opens at the bottom to the horizontal main road B B, which is 9 feet wide and 6 feet high, divided by a brattice in the centre throughout the whole length, for the downcast and upcast currents. The upcast shaft D, 7 feet diameter, has a ventilating furnace at the bottom, and contains a single winding apparatus. In a recess at the top of the second shaft C is fixed the air engine E for working the winding and pumping apparatus of the second shaft. The compressed air is conveyed to it by a cast iron pipe F, 10 inches diameter inside, carried down the main shaft, from a steam engine G at the surface, which is employed to compress the air.

The compressing engine is shown enlarged in Figs. 5 and 6, Plate 70.

Fig. 5 is a vertical section through the steam cylinder, air pumps, and air main; and Fig. 6 a sectional plan.

The steam cylinder H is 15 inches diameter with a stroke of 3 feet, and drives two condensing air pumps I I, which work alternately one on each side of the beam centre, delivering the air into the centre reservoir K from which it passes into the main pipe F. The beam is connected at the other end to a crank and flywheel L to equalize the motion.

The air pumps I I are 21 inches diameter, with a stroke of 18 inches; they are placed inverted, with the piston rods passing out below, where the stuffing boxes are not exposed to the pressure of the compressed air, and are worked with crossheads sliding in vertical guides by means of side rods from the beam.

The air pumps are shown enlarged in Figs. 7 and 8; they are fitted with ball valves, of which there are three sets to each pump, each set consisting of 44 brass balls, 2 inches diameter, arranged in three concentric rings, as shown in Fig. 8; the balls are confined by separate cages to a lift of ½ inch, as shown enlarged in Figs. 9 and 10. In consequence of the high pressure of the air, amounting to 30 lbs. per square inch, provision is made for preventing leakage through the valves, by a stratum of water constantly covering the piston valves and the delivery and inlet valves, as shown in Figs. 5

and 7, through which all the air has to pass. A small pump M, 3 inches diameter and 10 inches stroke, is employed to supply water for this purpose, and delivers it into the centre reservoir K, from which it flows through the small pipes N into each of the air pumps, during the period of their downward strokes, the quantity of water admitted being regulated by a cock O in each pipe. The surplus water is discharged at each upward stroke through the delivery valves, and flows over the top into the centre reservoir K, keeping the delivery valves also covered with water; in this way the compressed air is entirely discharged, and there is no loss of power from expansion of air behind the piston at the beginning of the downward stroke. The level of water in the centre reservoir is regulated by means of a gauge glass at the side. Any leakage of water past the piston valves and piston escapes through the suction or inlet valves, and is carried off by a waste pipe fitted to the casing of the air pumps.

The air pump barrels are lined with brass to prevent corrosion, and the pistons are also faced with brass, as shown in Fig. 7, and are made without any packing, being merely turned a good fit to the cylinders. The pumps have continued working the whole time since starting, a period of more than six years, working part of the time day and night, without requiring any repairs or adjustment; nothing has been done to them except replacing some of the valve cages which had been broken.

The usual speed of this engine is about 25 revolutions per minute, with a pressure of steam of 18 lbs. per square inch, giving a pressure of air averaging about 20 lbs. per square inch.

The air engine E, Figs. 3 and 4, Plate 69, at the lower shaft, has a cylinder 10 inches diameter and 18 inches stroke, and works usually at about 25 revolutions per minute; it is an old steam engine, and was formerly worked with high pressure steam. It was intended to be worked with air at 30 lbs. per square inch pressure, and at that pressure the heat generated in compression was expected to be very great; indeed calculation at the time gave nearly the melting point of tin. The great safety valve however for getting rid of the heat developed is, as was anticipated, the water upon the valves of the compressing engine, which absorbs the heat as soon as generated, a portion of the water passing off through the main pipe in the form of steam; this steam becomes condensed in the pipe, and provision is made for drawing off the water of condensation from time to time as it accumulates at the bottom of the shaft by means of a cock.

The pressure of the air at the lower engine is only about 1 lb. per square inch below the pressure at the compressing engine at the top of the pit. The absorption of heat on the sudden liberation of the compressed air from the lower engine at the discharge of each stroke causes so great a degree of cold that in winter the engine is often stopped by the formation of ice in the cylinder and exhaust pipe.

Mr. RANDOLPH observed that the most serious difficulty that had been anticipated when the apparatus was first designed was the considerable amount of heat that would be developed in the compression of the air, and the water had been employed originally for the double purpose of carrying off the heat and serving as a non-elastic medium for filling up the interstices among the valves, whereby the whole amount of the air which was introduced above the valves was sure to be expelled onwards, thus securing the full value of the power exerted in the compression; for these purposes it had proved completely efficient. He believed the temperature of the air in the main column varied from 90° to 140° Fahr., depending on the velocity of the working of the engine and the state of the atmosphere; and if it had not been for the use of the water, the engine would have been a failure in attempting to compress the air to 30 lbs. pressure per square inch, as the calculated temperature resulting from that amount of compression would be somewhere near the melting point of tin.

The three sets of valves were adopted to ensure the greatest action from the pumps; the lower suction valves were originally intended to be of gutta percha, to offer less resistance to the air entering, so as to allow the atmospheric pressure as nearly as possible to obtain in the lower part of the pump, when the piston was rising; on the descent of the piston the pressure accumulated to raise the weight of the brass valves in the piston. Brass suction valves were however employed, on account of the difficulty of obtaining spheres of gutta percha of suitable description at the time the engine was constructed; but no doubt could be entertained as to the superiority of gutta percha valves for the purpose. The apparatus had been in constant work for more than six years without any repairs, except replacing two or three of the valve cages, as had been mentioned in the paper.

The present case afforded opportunities of experimenting on various scientific questions, which might be well worth following out. The state of the thermometer at both the compressing and working engines under all the variations of pressure below the maximum might be noted: indicator diagrams might be taken from the compressing air pumps, and the compression curve would then show the whole time of the delivery of the compressed air, and would indicate the rise of temperature, which should be the greatest source of loss in this mode of applying power: the friction in the transmission of the air through the pipes might also be correctly ascertained. If instead of the old steam engine that was employed for working the lower shaft, there had been a properly constructed air engine below, cutting off the air at $\frac{1}{3}$rd stroke and expanding $\frac{2}{3}$rds or down to the atmospheric pressure, the true economy of the use of compressed air under such circumstances might have been demonstrated, and at the same time a comparison of the air expansion curve of the lower engine with the compression curve of the upper would accurately point out the amount of loss accruing.

Mr. **Rogers** considered it an excellent and well designed engine for the purpose, and thought there might be many other situations where such a mode of conveying power would prove advantageous. He thought the temperature of the discharged air must at all times be lower than the freezing point; and the cold air issuing into the workings would be very beneficial in cooling the mine, as the temperature of the coal itself was as high as 80° Fahr. in deep pits, and the air was often heated by the men and horses to 90° or more, causing serious inconvenience to the miners.

Professor **Rankine** remarked that the same principle had been applied by Professor Piazzi Smyth to the cooling of air for ventilation; compressed air was passed through tubes surrounded by water, so as to abstract the heat produced by the compression, and by being allowed to expand again was cooled.

Mr. **Rogers** had tried the experiments on this subject with Professor Warrington W. Smyth, and they had found that air at a pressure of about 10 lbs. per sq. in. was cooled down to 37° Fahr. temperature on expanding suddenly, which was quite in accordance with theory. On the Atmospheric Railway in South Devon he had observed, when it was working, a great heating of the air pump valves, from the compression of the air necessary to lift the large discharge valves at the speed at which the pumps had to be worked to maintain the required vacuum in the tube.

Professor RANKINE believed the first production of ice by the expansion of compressed air was effected by Dr. Gorrie in Florida, independently of the invention of the process for cooling air in this country.

Mr. FOTHERGILL remembered seeing an ice-making machine upon that principle in London about fourteen years ago.

Mr. HARVEY had seen the present engine at work, and was much interested by it. When a pit was troubled with firedamp, a steam engine and boiler could not be safely employed in the pit, otherwise he would consider that plan preferable. He was surprised to find only 1 lb. or 2 lbs. loss of pressure in the air at the end of so great a length of pipe; but an important advantage was obtained in this respect, by having the air main equal in area to the working cylinder, as in the present case. It was certainly more economical to carry compressed air down into the mine than high pressure steam, as there would be a serious loss of power in conveying steam to so great a distance as a half a mile. He had seen a pit in Fifeshire where steam was conveyed down from a boiler at the surface to work an engine under ground, but a very high pressure was required at the top to give a sufficient working pressure at the bottom.

Mr. FAIRBAIRN thought it would be very desirable to experiment upon the difference of temperature and pressure with both steam and air in descending a shaft, and hoped the subject might be taken up by Professor Rankine, as a good opportunity was afforded in the present instance for the trial of air. In the case of a powder mill at Constantinople that he remembered, compressed air was conveyed a distance of 300 yards to drive the machinery, but a great loss of power and pressure was experienced, from the friction in the pipes before reaching the engine.

The CHAIRMAN proposed a vote of thanks to Mr. Randolph for his communication, which was passed.

The following Paper, by Mr. Thomas Kennedy, of Kilmarnock, was then read:—

DESCRIPTION OF AN IMPROVED WATER METER.

The important uses to which a correct and durable water meter might with great advantage be applied have been highly appreciated and extensively felt by practical men, more especially in the case of water works in large cities and towns, where an unlimited supply to the inhabitants could not be kept up, on account of the injudicious use and waste which would thereby ensue. When the source of supply is limited or insufficient, great care is requisite to make the means suit the end; and the supply can therefore be let on only at intervals, during which the consumers have to draw as much as they require until the time of next supply. Even this system however is attended with more waste than there would be, if people were to pay for all that they draw. The question of constant supply has been entertained and considered in official quarters, but one great obstacle to its adoption, that has been reported, is the want of a thoroughly efficient meter.

The present policy of water companies is a fixed rate on rental, in the case of water supplied for domestic purposes; and a rate agreed upon by special contract according to the quantity supplied, in the case of water used for manufacturing and all other purposes. Hence, even under these arrangements, there is great room for the use of meters, it being most essential with large consumers to have a proper means of ascertaining the quantity supplied, which otherwise becomes a source of endless dispute and difficulty. Some companies fix a rate according to the size of service pipe, which may then run during day and night, whereas the supply wanted may be only partial, thereby entailing a very unequal rate, or great inconvenience and expense in erecting large cisterns.

The subject being thus one of general importance, many attempts have been made to produce an instrument capable of fulfilling the desired purposes. But it is remarkable that in this age of mechanical triumphs so many failures have occurred, and so much difficulty has been experienced in accomplishing what at first sight appeared such a simple matter. The non-elastic nature of the fluid, the impurities which generally exist in connection with a supply on an extensive scale, and the heavy pressure under a high column, were serious obstacles to the satisfactory working and durability of a machine intended to retain the pressure and to measure correctly.

The first meters that were brought most generally into use were made on a variety of plans, but all requiring to be placed above a cistern, from which the water after measurement was drawn; this plan was however attended with many disadvantages.

It is unnecessary here to enumerate the various other plans resorted to in pursuit of the object referred to; it will be sufficient to notice the leading features of those at present most prominently in use. The several varieties of meters may be reduced to two distinct classes, according to the principle on which they work; the first class comprehending all meters that measure by the velocity at which the water flows; and the second class, those measuring by capacity.

Meters on the former plan are rotary, and are best constructed by placing a wheel, fan, spiral, or modification of revolving arms, on the principle of "Barker's Mill," in the water-course, so as to be propelled by the force of the water's motion, an indicator or counting apparatus being attached. This principle of action embraces a large number of inventions; but in the writer's opinion it does not admit of surmounting the difficulties of correct measurement under variable pressure and velocity, because the whole body of water in the chamber containing the working parts has to be put in motion with sufficient force to drive the rotating apparatus, before there can be any indication; and consequently small quantities of water can pass and be drawn off without registration. Another point of difficulty is to ensure a proper rate of rotation under a varying velocity of flow, in exact proportion to the quantity of water passing off. As regards durability and the confidence to be placed in continuous working and uniformity of registration, too much depends on the nice rotation of the mechanism; and this for the sake of sensibility to motion must be supported on centres which are liable to wear and allow of oscillation. Various causes may also increase the friction, or injure the revolving parts, so as to cause inaccuracy.

In the second class of meters, measurement by capacity is best effected by means of a cylinder and piston.

The meter described in the present paper is constructed on the principle of measurement by capacity, and is made with a cylinder and piston; it has been found to measure correctly and uniformly under every variation of pressure or velocity of flow. The water is discharged in a steady and continuous stream, without any shock, concussion, or intermission; the piston moves with great ease, and is likely to be durable and easily kept in order.

The meter is shown in Figs. 1, 2, and 3, Plate 71.

Fig. 1 is a side elevation of the meter, with the casing removed to show the internal mechanism, the measuring cylinder being in section.

Fig. 2 is a vertical section of the meter, and Fig. 3 a plan with the upper part of the casing removed.

The cylinder A is fitted with a water tight piston B, the rod of which carries a rack C, gearing into a pinion D connected with the counting apparatus. The water is admitted alternately above and below the piston by means of a fourway cock E, which is reversed when the piston arrives at either end of the cylinder. The reversing is effected by a tumbler F falling over alternately upon two arms G G on the spindle of the fourway cock E, the tumbler being raised during each stroke of the piston by a stud or catch H fixed on the pinion D.

The piston B is rendered water tight by a "rolling packing," consisting of a ring I of vulcanised india rubber of circular section, which is drawn on the body of the piston like an india rubber band; in consequence of its elasticity the ring accommodates itself so completely to the space between the body of the piston and the cylinder as to make a water tight packing in a simple and effectual manner. The rolling action of the packing ring diminishes the friction, and consequently the liability to wear and tear, and the packing being impervious to water is not liable to rot or decay; this is one of the peculiarities of the meter, which is presumed to have overcome a material difficulty. It has been found from experience that no other packing would endure for a reasonable length of time; any other material which might be fitted water tight causes too much friction, and is liable to become leaky after wear; even the india rubber would be open to the same objection, were it not for its rolling action. It may be observed that the rolling packing, although admirably suited to the present purpose, would not be serviceable on a piston or plunger which had to meet much resistance, being efficient as a water tight packing only when exposed to nearly equal pressures on both sides, as in the present case, the piston merely floating in a current, and raising only the weight of the tumbler F by which the cock E is worked.

The cock or valve E, shown in Figs. 4 and 5, is so constructed as to reverse the water to opposite ports without the aid of an air vessel, causing not the slightest increase of friction, or any stoppage or check to the uniform flow of the water. The valve barrel is formed on the plan of a fourway cock, the key or plug being made more on the principle of a steam throttle valve; it does not completely cover the ports in crossing to reverse, but as the central position of the valve across the port is but momentary, the escape of water through the valve, which saves the recoil, is so inappreciable in quantity as not to cause a variation of one per cent. under the most extreme trial.

The tumbler or weighted lever F, which reverses the valve, is worked from the piston B, the rod of which carries the toothed rack C in gear with the pinion D; the shaft of the pinion is in the same line with the valve plug or key, on which is fixed a pair of bent lever arms G G, Fig. 5, placed for the tumbler F to fall against on either side. During the stroke of the piston, the tumbler is raised up to a vertical position by means of a lifter or stud H attached to the pinion D; but being loose on the shaft of the pinion, immediately on passing the centre it falls over by its own weight, striking the upraised arm of the valve E, which is instantly reversed. The water which has passed into the cylinder is then discharged by the return stroke of the piston, and the action continues in the same manner as in an ordinary high pressure steam engine. The tumbler is prevented from turning the valve too far over by a buffer K suspended loose from the spindle of the pinion D; the buffer receives the surplus force of the fall of the tumbler, and is limited to a small motion by the checks L; its resistance is increased by the friction of the guides M between which it vibrates.

The indicating apparatus N is contrived to suit a variable flow of the water and its non-elastic condition, as it was found that the piston would not work to a definite length of stroke when the volume of flow varied. When the discharge was great the stroke was a little longer than with a small discharge; and to have made the piston work between checks, and count the strokes for indication, as has been done in other cylinder and piston meters, would not answer, because the actual distance travelled by the piston has to be measured, and the piston must have a free and independent action, and be allowed to float in accordance with the current; otherwise severe reaction, concussion, and derangement would be produced. Therefore to obtain accurate registration, the indicating apparatus N is attached to the shaft of the pinion D, and made to move uniformly forward in one direction by means of a pair of ratchet wheels, while the piston traverses either upwards or downwards, giving always accurately the distance travelled by the piston; then the area of the cylinder being known, the indication of the quantity of water passed through must be correct, whether long or short strokes be made by the piston.

The amount of head pressure required to move and work this meter is very small, and would rarely be felt of any importance.

The meters for actual use are made so strong in all their parts as to stand the heaviest pressure in use in this country; they will work in any situation with complete freedom and accuracy, irrespective of the size, length, or distance of inlet or outlet pipes; and the meter may be placed on any part of the line of service pipe leading to the premises to be supplied. After passing through the meter, the outlet pipe may be branched in any direction, and the water drawn off in any quantity by as many outlets or cocks as may suit the convenience of the consumer; so that by the use of this meter the amount consumed is correctly registered, and no cistern is required where a constant supply can be obtained.

At the Nottingham Water Works one of these meters was tried, having the inlet pipe 100 feet long, upon which was fixed a pressure gauge, to detect shocks or variation of pressure. When at work the pressure at the meter ranged from 95 to 100 feet effective head, the total head being 130 feet; the discharge was 2000 gallons in 1¼ hours, this quantity being afterwards measured and found to be quite correct. Though the trial was frequently repeated, no decided shock was perceived when the meter was at work.

At the Halifax Water Works a series of experiments was recently tried with one of the meters. A new meter was used with 1 inch outlet and inlet from a 2 inch main. The pressure upon the pipes was equal to a head of water 180 feet high. The test as to accuracy of measurement was made by filling from the delivery cock a standard gallon measure one hundred times. At the conclusion of the trial the meter registered 101 gallons, or 1 per cent. too much. On a second trial made in the same manner the result was 100 gallons exactly. To ascertain the loss of pressure sustained by the passage of water through the meter, a ¼ inch nib was placed upon the outlet, and played with a vertical jet in front of a measured surface; the water was then delivered 45 feet high. On disconnecting the meter, the same jet was found to deliver the water as nearly as possible to the same height as through the meter.

In reference to the practical application of these meters, a good example may be taken from the town of Preston, where they are extensively used by the corporation. In November 1854 one meter was sent there for trial, and approved of; subsequently meters were put on all the large consumers, and now about 120 are in operation there. Previous to the use of the meters, the water was estimated at 9d. per 1000 gallons, but no satisfactory rule could be applied as to quantity; on application of the meters the rate was reduced to 6d. per 1000 gallons, and notwithstanding this reduction, a great increase was made to the revenue, and doubtless a vast saving in the waste of water. After twelve months' constant working of these meters, which had cost no expense from wear and tear, a number of them were again tested, and found to work as well and measure as accurately as when first put up.

The meters have also been used extensively for measuring the feed water supplied to steam boilers, and a considerable number have been applied for this purpose by the Government.

As regards the quantity which each size of meter would discharge, no definite rule can here be given; much depends on circumstances connected with the pressure and the pipes; but as a general rule, where a pipe of 1 inch bore will discharge from 10 to 35 gallons per minute, a 1 inch meter should be put on; but if by extraordinary pressure and freedom of delivery a 1 inch pipe would discharge a greater quantity, then a $1\frac{1}{2}$ inch meter should be put on, and other sizes in the same proportion, no inaccuracy being produced by whatever size of pipe may be put to the meters, and the above restraint being recommended only so as not to overwork them. The sizes of meters at present made are $\frac{3}{8}$, $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, 3, 4, and 5 inch inlet.

As regards the manufacture of the meters, it may well be supposed that the highest degree of perfection could not at first be attained; practical difficulties, which experience alone could show, interposed; the valve was placed too far from the cylinder, the ports were not wide enough, and the opposite currents meeting with too great velocity caused a shock; also the packing of the valve spindle gave some trouble. These difficulties have been most successfully overcome, and the meter has now attained such a state of completeness as it is hoped will satisfy the demands and conditions of a good water meter.

DIRECT-ACTION MARINE ENGINE

Plate 72

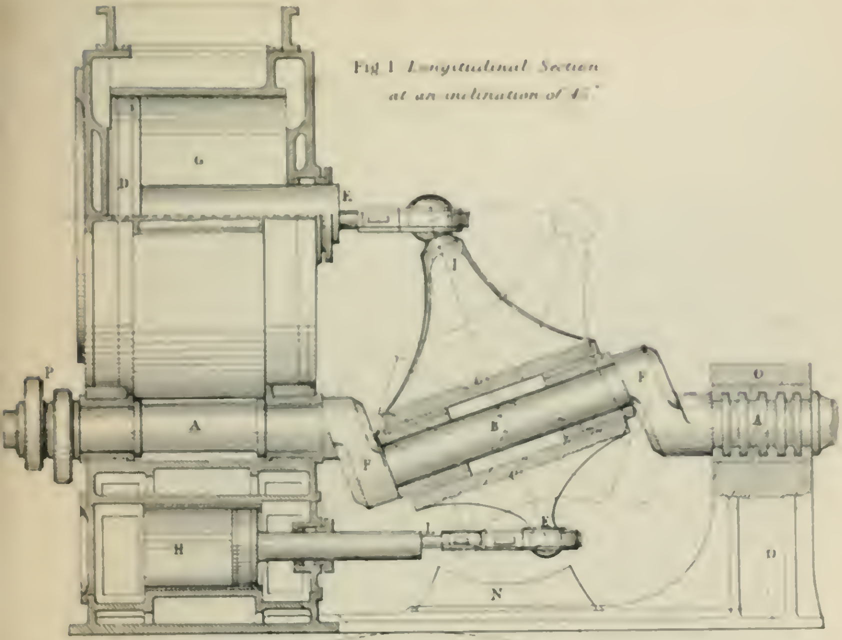
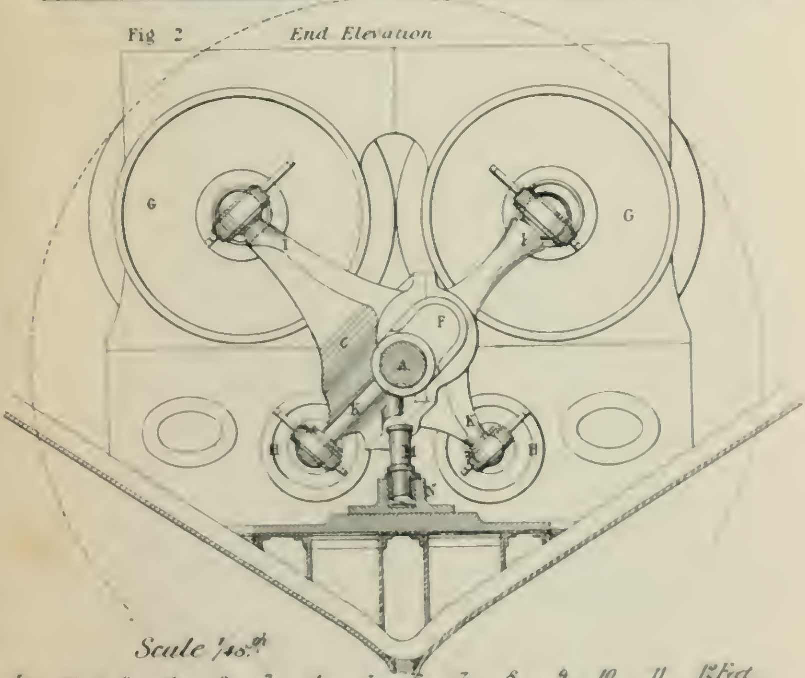


Fig 1 *Longitudinal Section at an inclination of 45°*

Fig 2 *End Elevation*



Scale 1/48th

Ins. 12 6 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet

(Proceedings Inst. M. E. 1856. Page 160.)

IRON CONSTRUCTION OF FOUNDRY

Fig. 1. Longitudinal Section of Foundry

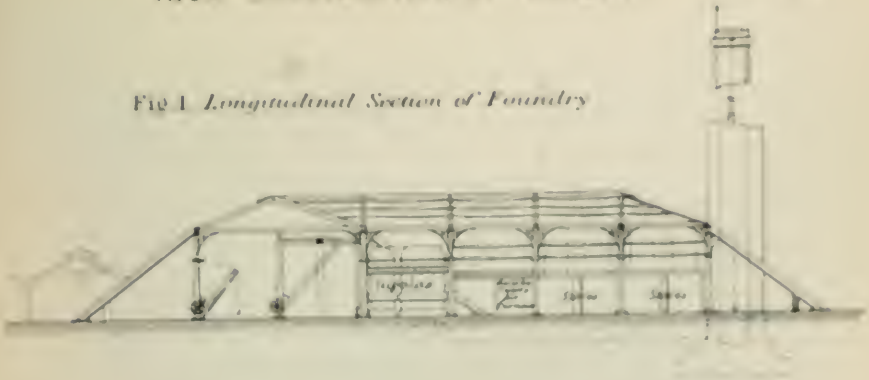
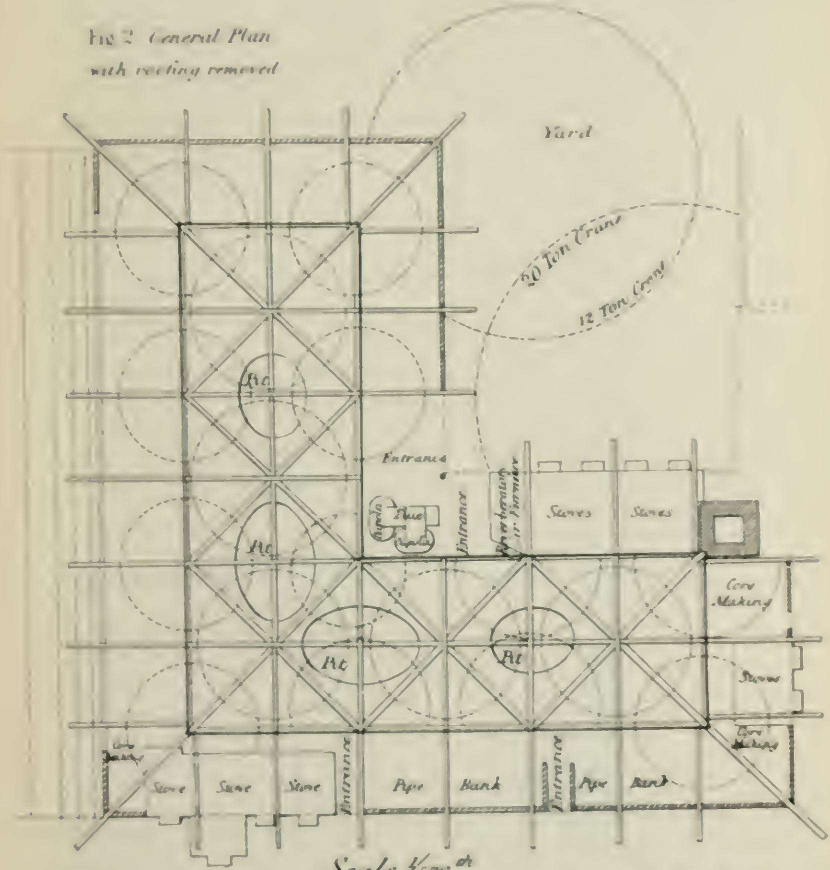


Fig. 2. General Plan with roofing removed



Scale 1/576th

0 5 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 Feet

(Proceedings Inst. M. E. 1856 Page 165.)

IRON CONSTRUCTION OF FOUNDRY *Plate 74*

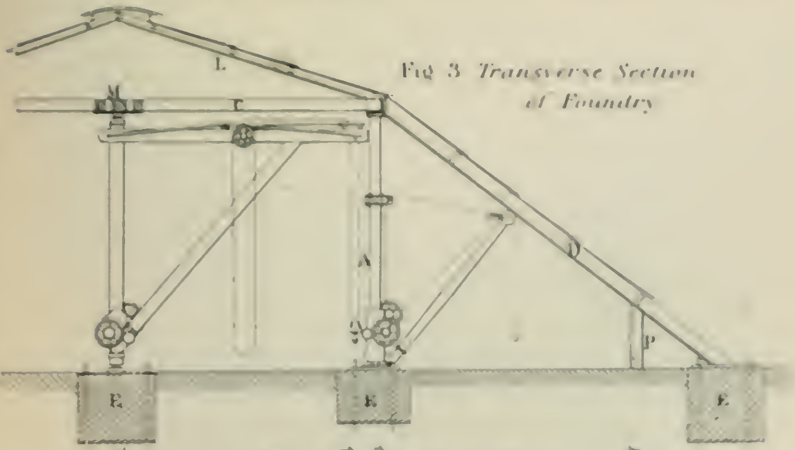


Fig 3 *Transverse Section of Foundry*

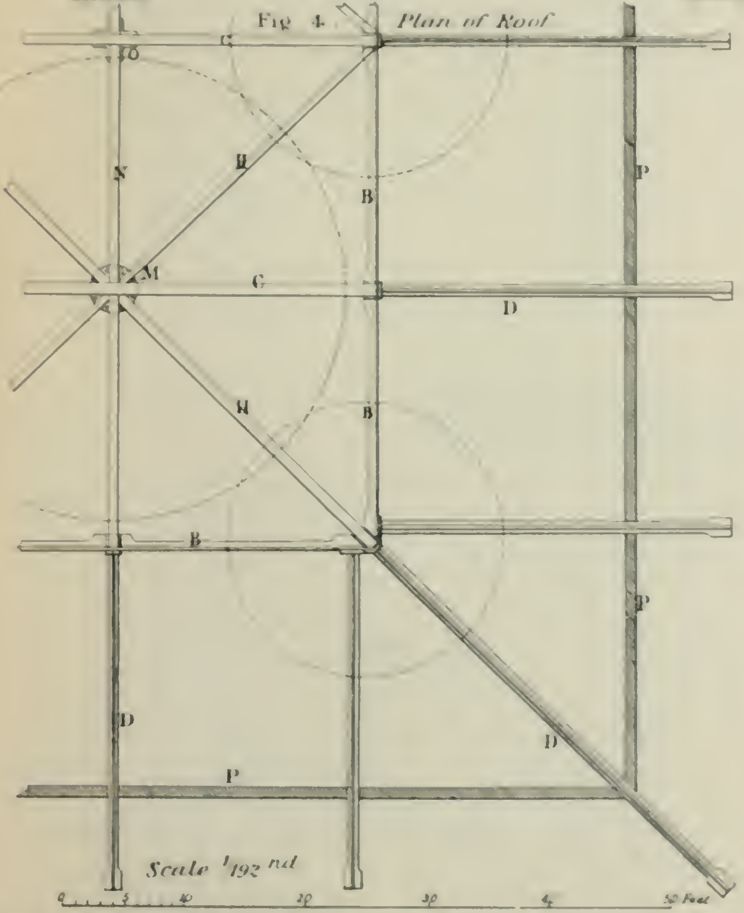


Fig 4 *Plan of Roof*

(Proceedings Inst. M.E. 1856 Page 165)

IRON CONSTRUCTION OF FOUNDRY

Details of Junction of Columns Girders and Struts

Fig 5. *Plan*

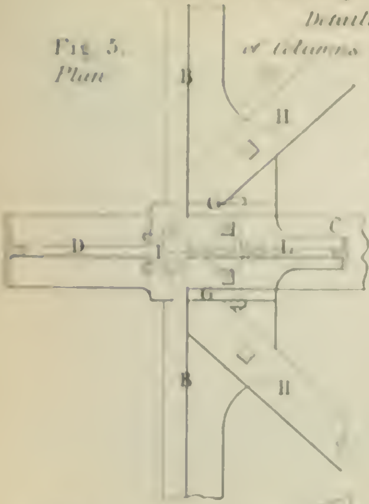
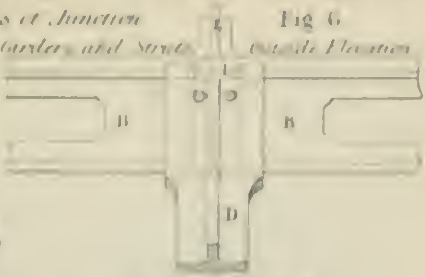


Fig 6. *Outside Elevation*



Detail of Columns

Fig 10 *Plan at Top*

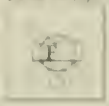


Fig 9 *Elevation*

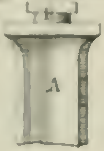


Fig 11 *Section*

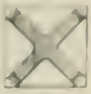


Fig 7 *Section*

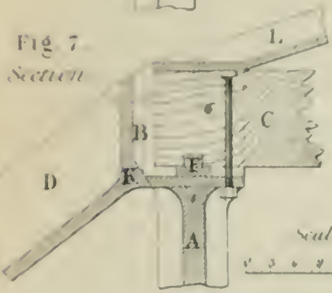
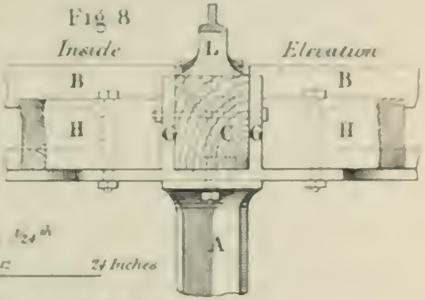


Fig 8 *Inside Elevation*



Scale 1/24th 0 3 6 9 12 24 *Inches*

MOULDING APPARATUS.

Fig 12 *Side Elevation* *Longitudinal Section*

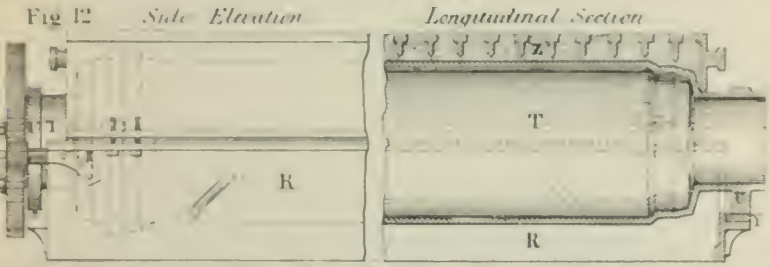
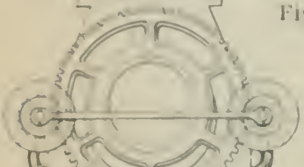


Fig 13. *Front Elevation*



Back Elevation with Flask in Section

Fig 14.

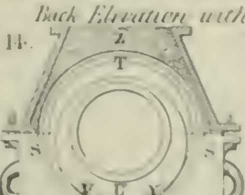
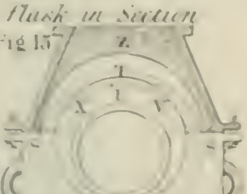


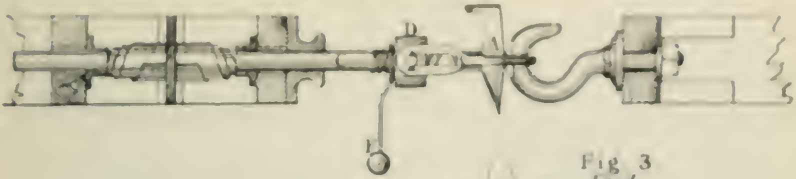
Fig 15.



Scale 1/30th Inch 6 0 1 2 3 4 5 6 *Feet*

CENTRAL BUFFING APPARATUS

Fig 1. *Side Elevation*



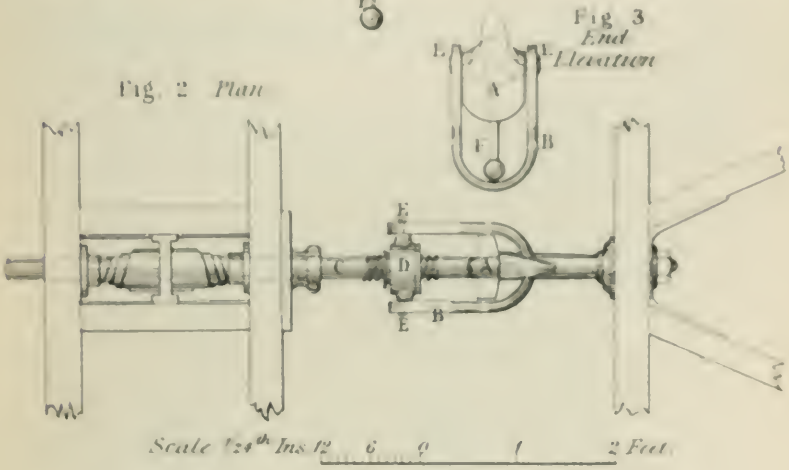


Fig 3 *End Elevation*

Fig. 2 *Plan*

Scale 1/24th Ins 12 6 0 1 2 Feet

PRESERVATION OF TIMBER.

Fig 1.

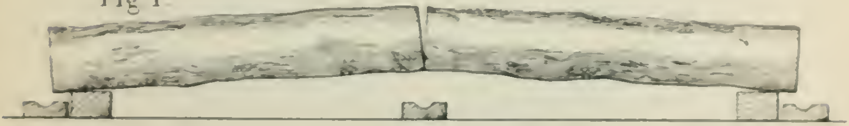
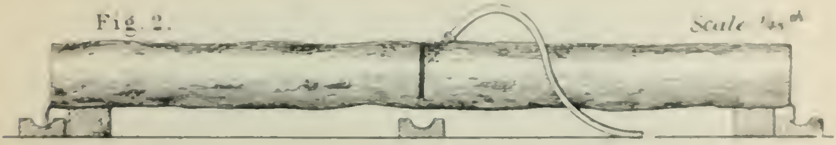


Fig. 2.



Scale 1/48th

Fig 3.

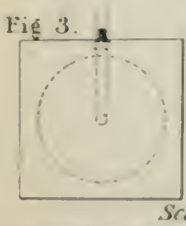
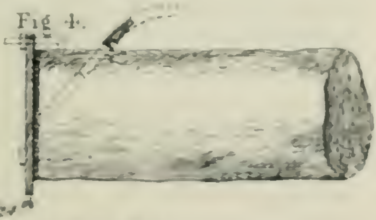
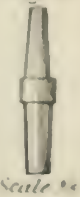


Fig 4.



Scale 1/24th

Fig 5



Scale 1/4th

(Proceedings Inst. M.E. 1856 Page 175)

Fig. 1. *Side Elevation of Bour Pan*

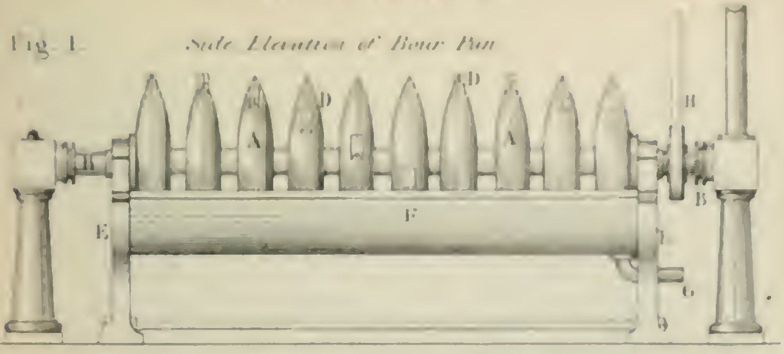


Fig. 2. *Vertical Section of Disc*

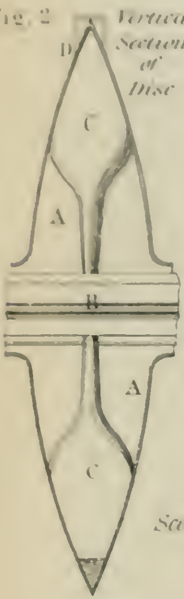
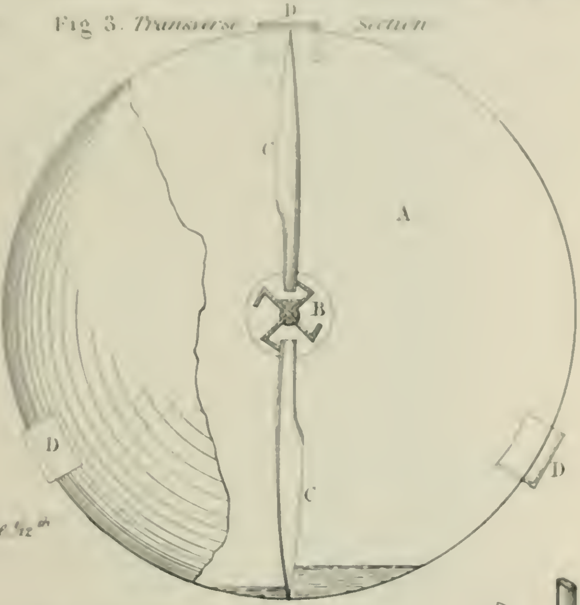
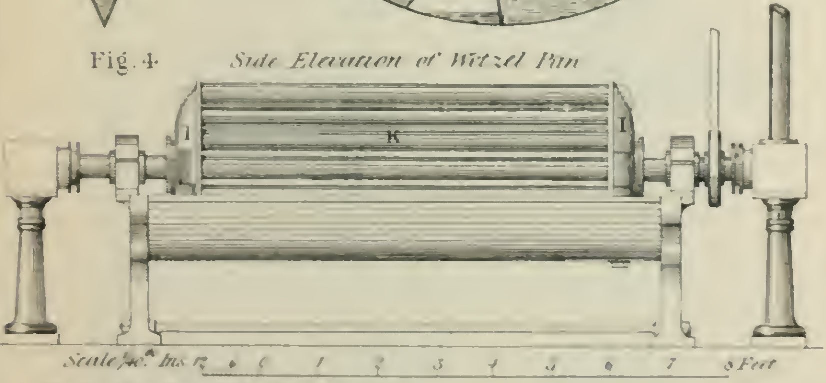


Fig. 3. *Transverse Section*



Scale 1/12th

Fig. 4. *Side Elevation of Wetzel Pan*



(Proceedings Inst. M.E. 1856 Page 179.)

SURFACE CONDENSER

Fig 3 *Plan of Tube Plate*

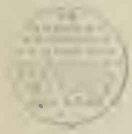
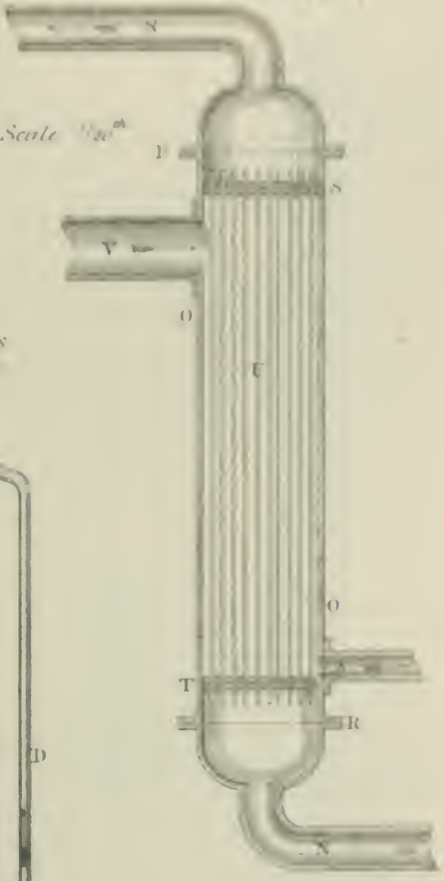
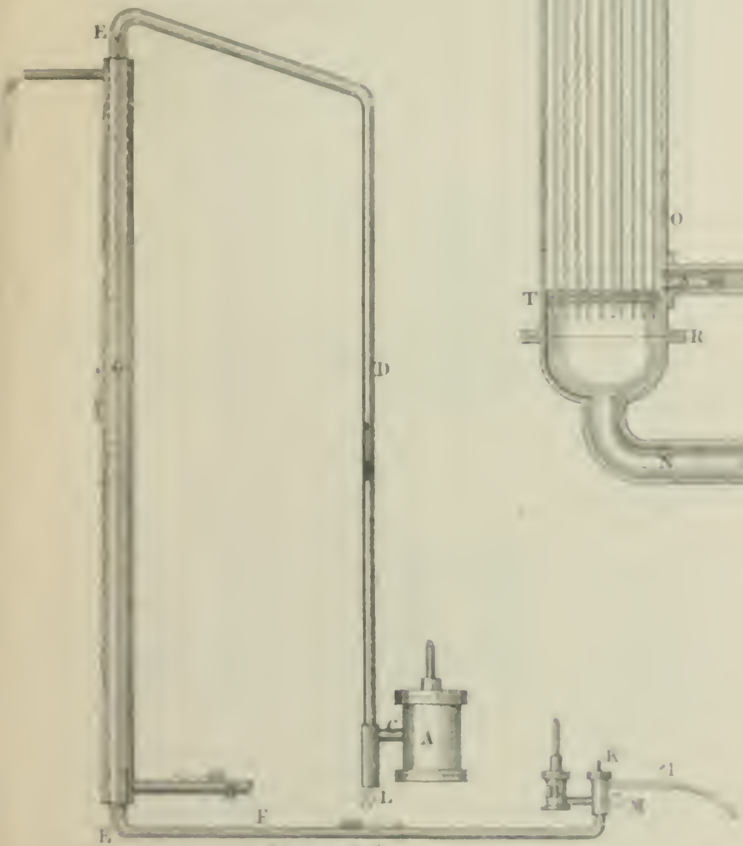


Fig 2 *Vertical Section of Proposed Surface Condenser*



Scale 1/20th

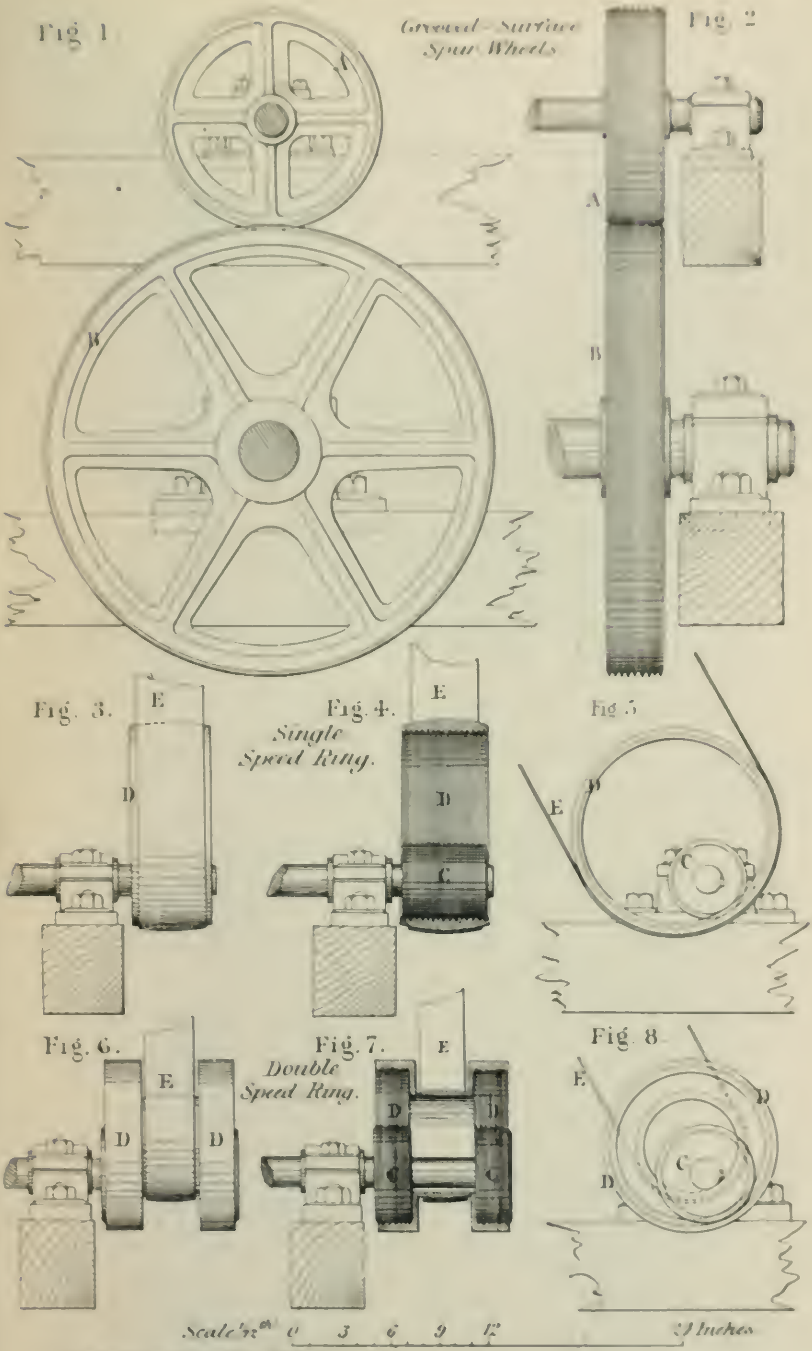
Fig 1 *General Arrangement of Condensing Apparatus in experimental engine*



Scale 1/30th

Ins. 12 6 0 1 2 3 4 5 6 *Feet*

FRICTIONAL GEARING *Plate 79*



(Proceedings Inst. M.E. 1886 Page 203.)

FRICTIONAL GEARING

Grooved Surface Bevel Wheels

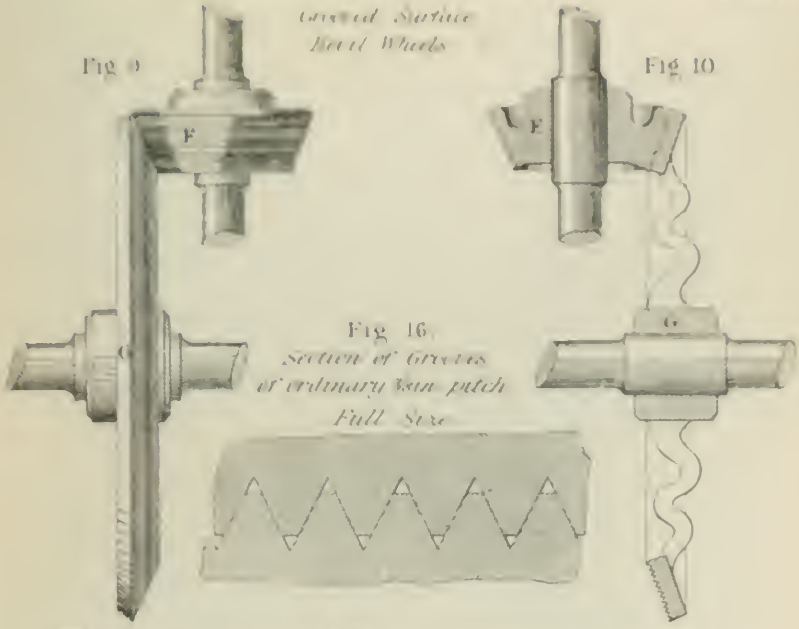


Fig 9

Fig 10

Fig 16.
Section of Grooves of ordinary ⅜in pitch Full Size

Engaging Clutch

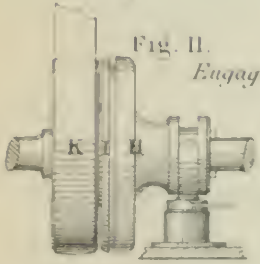


Fig. 11.

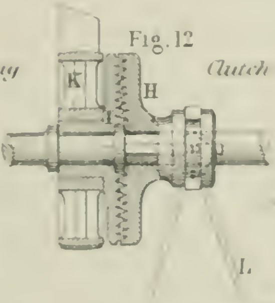


Fig. 12

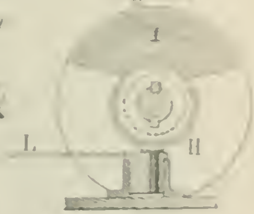


Fig 13

Reversing Gear

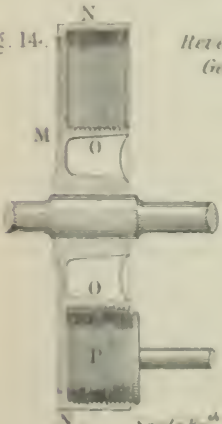


Fig. 14.

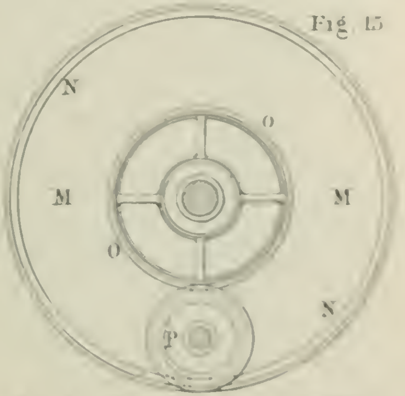


Fig. 15

Scale ⅛th 0 3 6 9 12 24 *Inches*

(Proceedings Inst. M. E. [illegible] Page [illegible])

STATIONARY STEAM BOILER

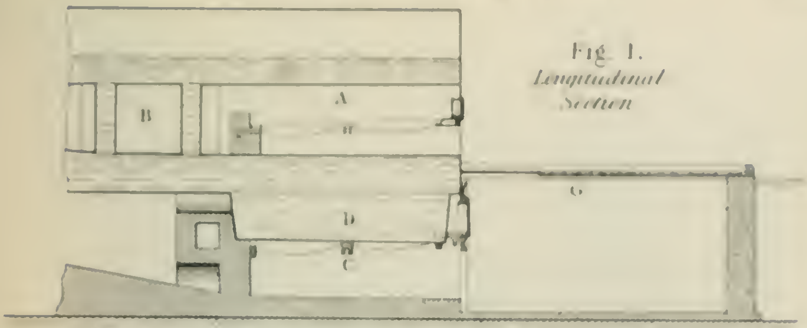


Fig 1. Longitudinal Section

Fig 2. Sectional Plan

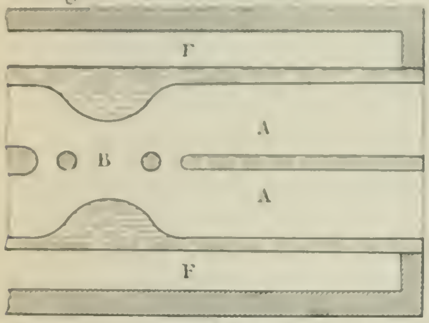
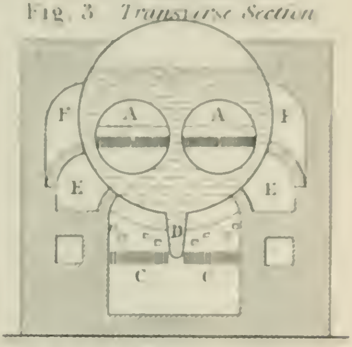


Fig 3. Transverse Section



Scale 1/96th 0 1 2 3 4 5 6 7 8 9 10 11 12 Feet

IRON WAR SHIPS.

Fig 1. Transverse Section

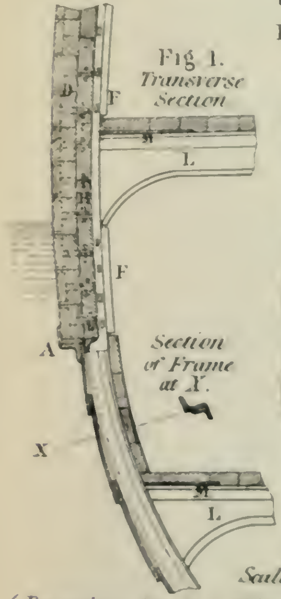
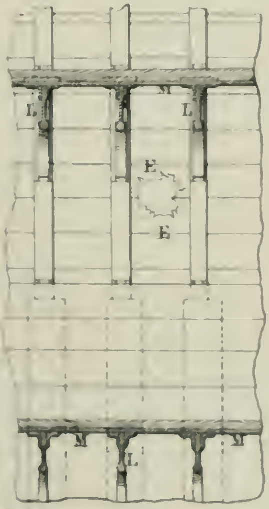
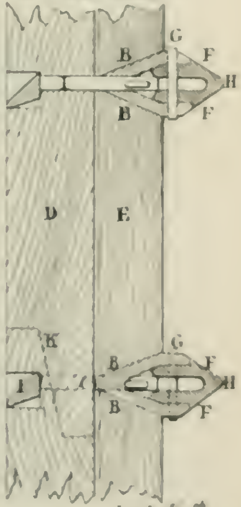


Fig 2. Longitudinal Section.



Scale 1/48th 0 1 2 3 4 Feet

Fig. 3. Enlarged Section of Iron Frames.



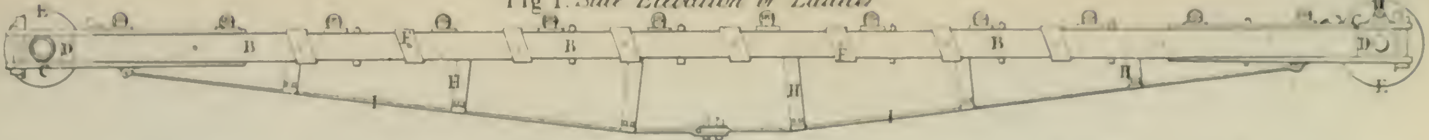
Scale 1/12th

(Proceedings Inst. M.E. 1856. Page 213)

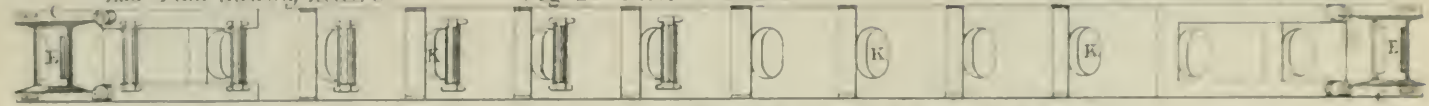
DREDGING LADDER.

Plate 52.

Fig 1. *Side Elevation of Ladder*



Half Plan showing Rollers Fig 2. *Plan of Ladder* *Half Plan with Rollers removed*



Scale 1/96th 0 1 2 3 4 5 6 7 8 9 10 11 12 18 24 Feet

Fig 3. *Transverse Section*

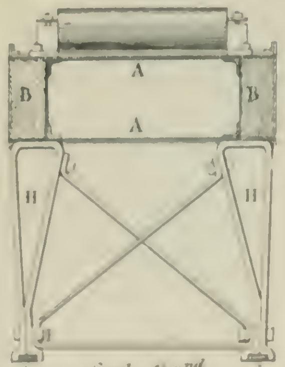
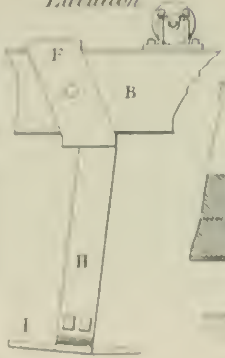


Fig 4. *Side Elevation*



Scale 1/32nd

Ins 12 6 0 1 2 3 4 Feet

Fig. 5. *Longitudinal Section of Dredger showing working position of Ladder*

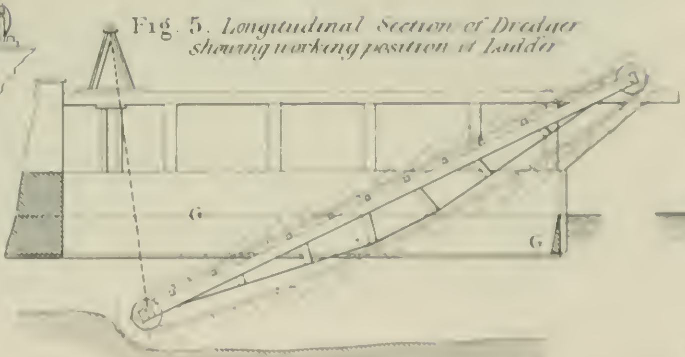
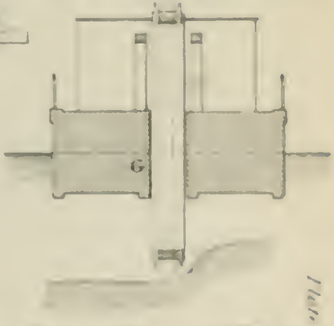


Fig 6. *Transverse Section*



Scale 1/360th 0 5 10 20 30 40 50 60 Feet

(Proceedings Inst. M. E. 1856 Page 218.)

FILE CUTTING MACHINE.

Plate 83.

Fig 2. *Front Elevation.*

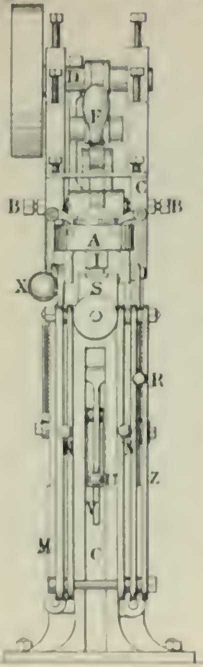


Fig. 1. *Side Elevation.*

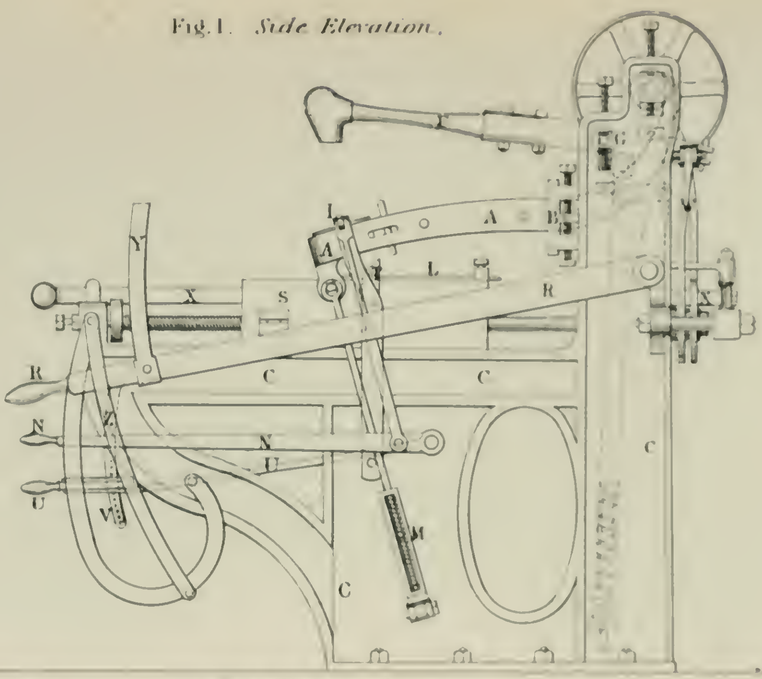
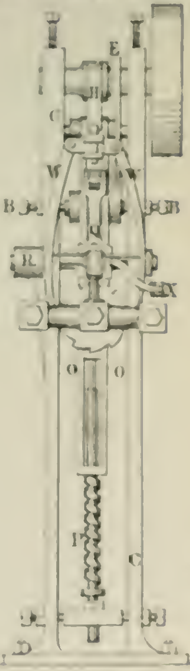


Fig 3. *Back Elevation.*



Pl. 11 83.

(Proceedings Inst. M. E. 1856. Page 226.)

Scale 1/20th Ins. 12 6 0 1 2 3 4 5 Feet

FILE CUTTING MACHINE.

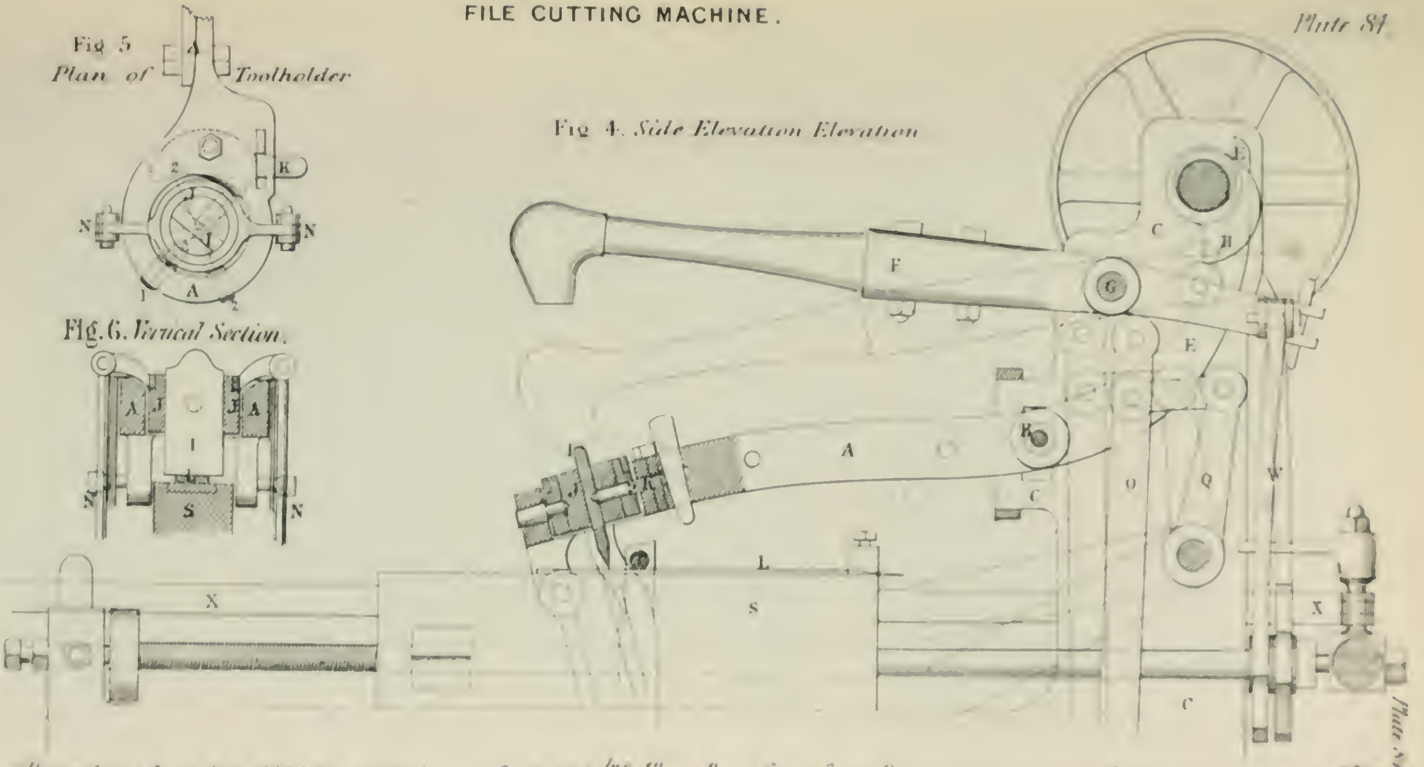


Fig 5. Plan of Toolholder

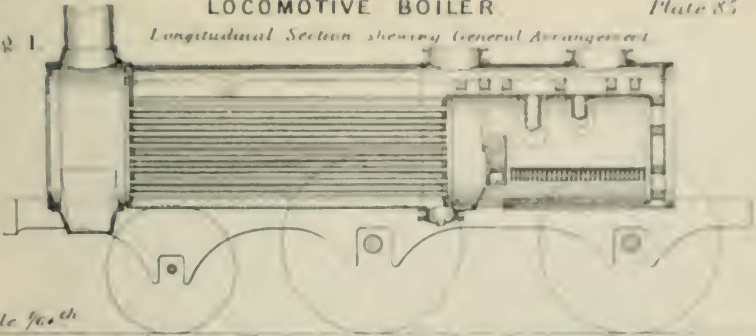
Fig. 6. Vertical Section.

Fig 4. Side Elevation Elevation

(Proceedings Inst M.E. 1856 Page 226.)

LOCOMOTIVE BOILER

Fig 1. *Longitudinal Section shewing General Arrangement*



Scale 1/64th

Fig 4 *Transverse Section in front of Grate*

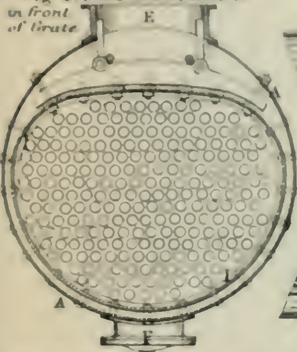


Fig 2 *Longitudinal Section Enlarged*

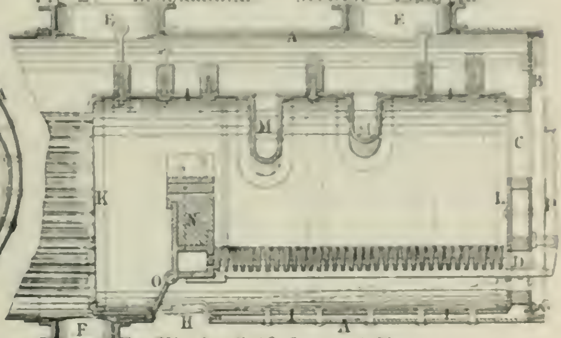


Fig 5 *Transverse Section through Grate*

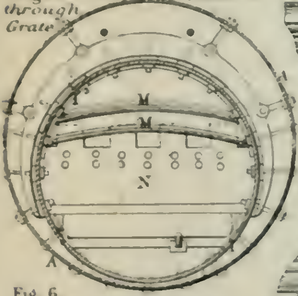


Fig 3. *Half Sectional Plan*
Half Plan

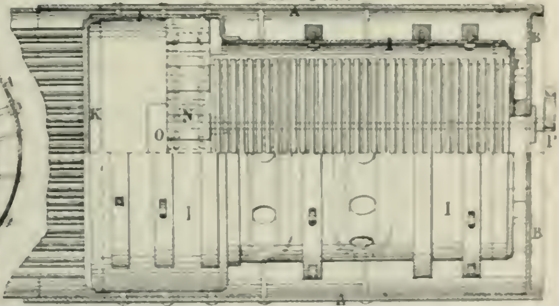


Fig 6 *End Elevation*

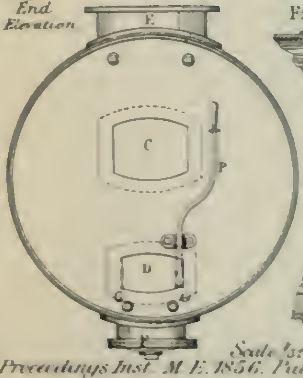
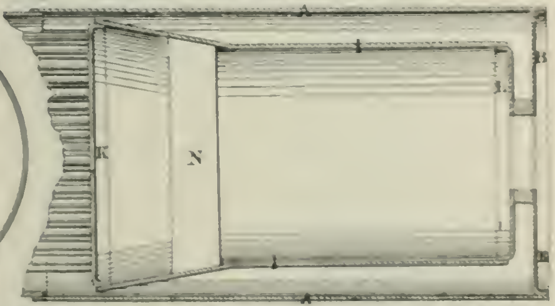


Fig 7 *Sectional Plan of Bell mouthed Firebox*



Scale 1/32nd *Ins 12 6 0 1 2 3 4 Feet*

(Proceedings Inst. M. E. 1856. Page 233)

LOCOMOTIVE BOILER.

Fig 1. Longitudinal Section

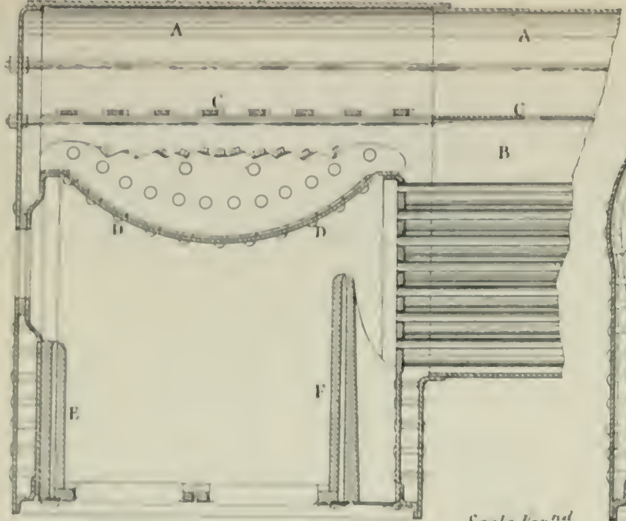
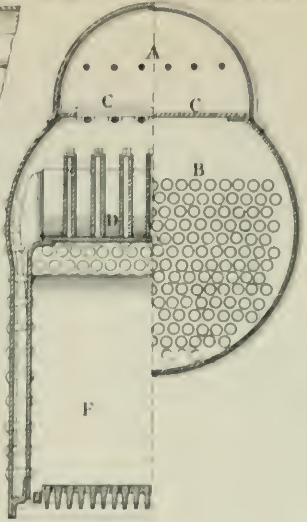
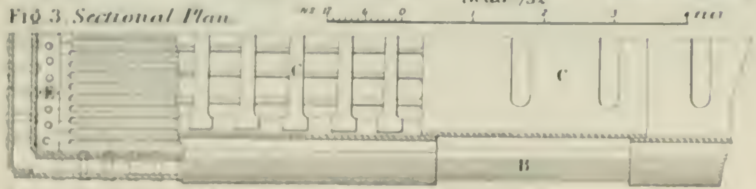


Fig. 2 Transverse Section



Scale 1/32nd

Fig 3. Sectional Plan



Proceedings Inst. M.E. 1856. Page 236)

ROTARY WATER METER.

Fig 1. Sectional Plan inverted

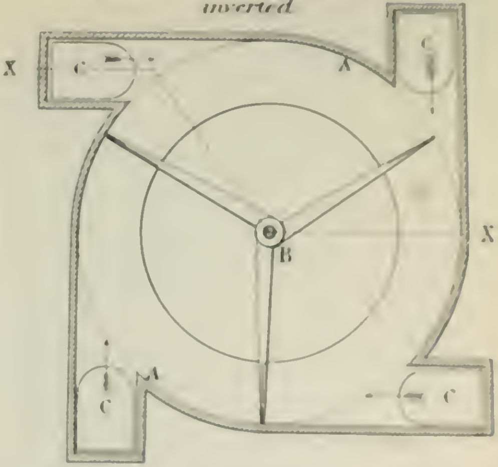
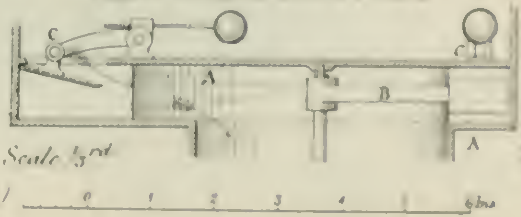


Fig 2. Vertical Section on XX



Scale 1/3rd

(Page 243)

Plate 86

STEAM DASH WHEEL

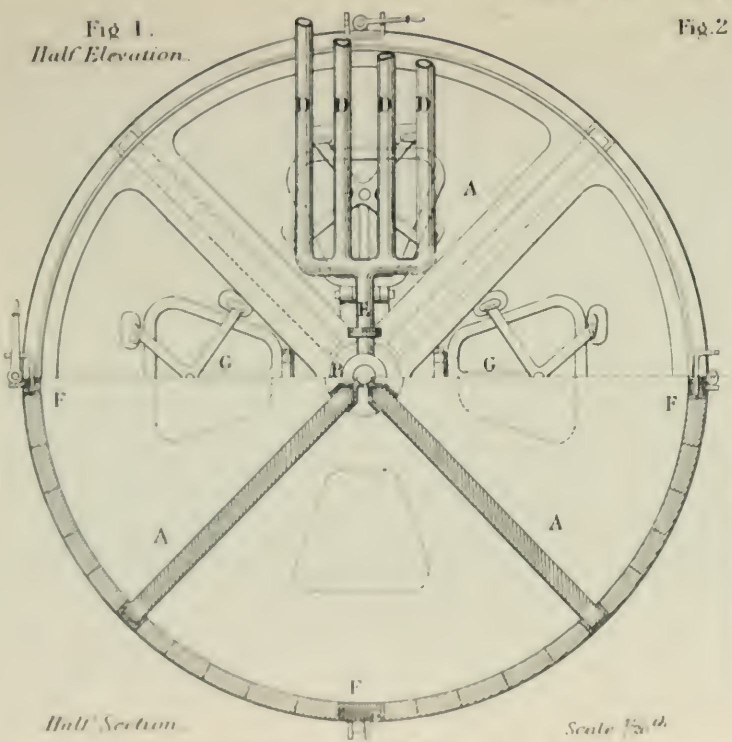


Fig 1.
Half Elevation.

Half Section.

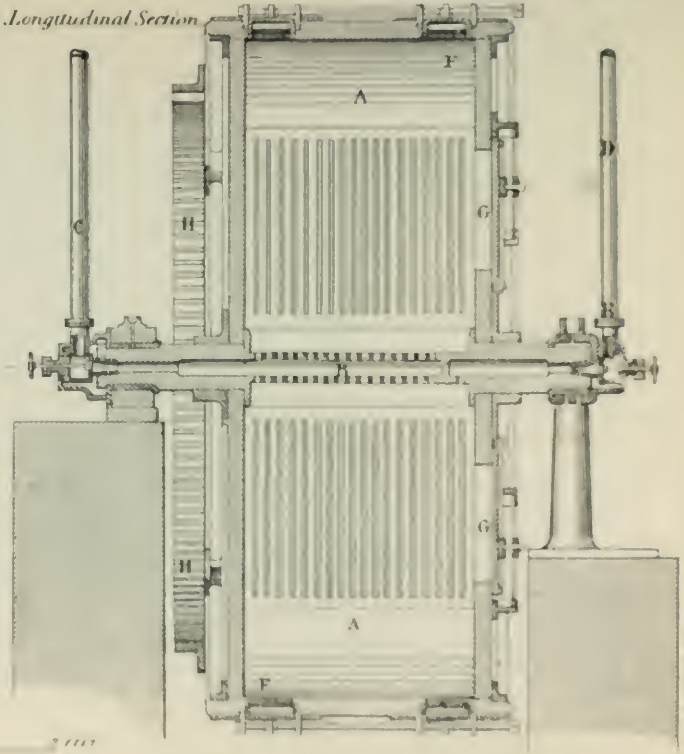


Fig. 2. *Longitudinal Section*

Scale 1/24th

(Proceedings Inst. M. E. 1856. Page 239)

Mr. **Kennedy** exhibited one of the meters in operation at different speeds, having a glass cylinder and casing, showing the action of the rolling packing of the piston and the tumbler and cock.

The **Chairman** enquired how many of the meters were now in use.

Mr. **Kennedy** replied that about 1300 of the meters of various sizes were now at work.

Mr. **Muir** stated that he had been present at some of the experiments at Halifax, where different meters had been tried, but doubted the accuracy of the results, because the index was not fully graduated to show single gallons, and the exact quantity had been guessed at from larger divisions, he was satisfied however that the meter described registered correctly when in good order. He understood that one of the meters in use there had been found to stick from some sand getting in through the screen, and other meters had also stuck from other causes. He thought the meter involved a defect in principle, from the fact that if the tumbler from any cause stopped in its fall, it would either allow a continued delivery without registering, or would stop the supply of water altogether.

Mr. **Neilson** had tried a piston meter some 20 years ago, but had found a fatal difficulty in the leakage. Many attempts had also been made for several years, to construct water meters on the principle of the gas meter; but by this plan the pressure could not be communicated, and gas meters even could not be said to be perfect. The great difficulty in water meters arose from the variable pressures under which they were required to work, and he thought the cylinder meters, such as the present, were the best that were in use; he was much pleased with the rolling packing, which was certainly an ingenious and simple mode of preventing leakage with little friction. It was important to have as little machinery as possible in a water meter, and he thought the meter now described admitted of improvement in that respect.

Mr. **Kennedy** considered that the rolling packing ring rendered the piston now perfect in respect of packing, and a pressure of only 18 inches head of water was required to work the piston including the tumbler; the piston was made of beech wood. Several meters were working on steam boilers at a factory at Leeds with good results, tending to prevent waste of fuel by showing the proportionate quantity of water evaporated in the boilers. The cost for repairs of a large number of meters at Preston had at present amounted to not more than £3, and the charge for upholding the meters for 10 years was calculated at 2½ per cent. per annum on the original cost. He thought the cock would not be liable to stand across the port so as to leave it permanently open by any risk of the tumbler sticking in its fall, as had been supposed. The packing of the spindle of the cock had been a serious practical difficulty at first, but he had adopted now a good plan of packing, consisting of a small cupped leather; this had been found quite water tight and very durable, and gave little friction.

The CHAIRMAN asked how the rolling packing ring was found to wear, and whether any of the rings had been worn out yet.

Mr. KENNEDY replied that none of the rings had been worn out yet, and the first which had been at work at Preston for two years appeared as good now as when put to work. The only cases of failure that he had met with in the whole number at work were two instances where the ring had given way from a defect in the joint of the india rubber. Where a meter was employed to measure water in connection with a pump, as in supplying a boiler, every stroke of the pump caused a sudden oscillation in the stroke of the meter; but this was entirely prevented by placing a valve between the meter and the boiler, and the indication would then be given with great accuracy.

A vote of thanks was then passed to Mr. Kennedy for his paper and the working model exhibited.

The following Paper, by Mr. Edmund Hunt, of Glasgow, was then read :—

DESCRIPTION OF A DIRECT-ACTION MARINE ENGINE FOR SCREW PROPULSION.

The engine forming the subject of the present paper, which is the invention of the writer and Mr. Alexander Morton, of Glasgow, is especially designed for driving the screw propeller, and adds one more to the already numerous designs to which that instrument of propulsion has given rise. In a steam vessel every inch of space is valuable, and the smaller the space into which the engines can be got, the more suitable they are, provided simplicity of details and convenience of arrangement are not lost sight of, together with facility of access to all parts requiring attention for adjustment or renewal. At the present time more particularly a compact arrangement of marine engine is called for, for driving the screw propeller, since vessels with auxiliary power are likely to be extensively adopted, in consequence of the success of the "Royal Charter" and other vessels furnished in that manner. Where the very object of using auxiliary power is to save space, and where the steam power is only used when the vessel would otherwise be delayed by calms, it is obvious that it is more than ever desirable to assist in attaining that object by making the engines as compact as possible, to take up the least possible room.

It is in the class of engines for driving the screw direct, or without the intervention of gearing to increase the speed of rotation, that the designs of the greatest compactness are to be found. In all these engines, with one or two exceptions, the steam cylinders have been placed with their axes at right angles to the propeller shaft, either in vertical, horizontal, or inclined positions. It must however have occurred to many persons designing marine engines that if the cylinders could be placed with their axes parallel to the shaft a much more compact arrangement would be obtained than with the cylinders in the ordinary positions at right angles to the shaft. The difficulty hitherto in the way of such a contrivance has been the want of suitable means of imparting a rotatory motion to the shaft derived from the reciprocatory motion of the steam pistons, when the cylinders are placed parallel to the shaft. An intermediate shaft and gearing are obviously inadmissible, as their introduction would neutralize any saving of space that might otherwise be obtained by the arrangement. One or two attempts have been made to realize the compactness which the parallel arrangement seems to promise, by using contrivances for making th steam pistons act directly on the shaft when placed parallel to it in this manner. Thus it has been proposed by different inventors both here and in America to make the outer ends of the piston rods work in grooves formed obliquely upon a drum fixed on the shaft; the oblique or wedge-like action of the piston rods in the grooves of the drum causes it to revolve; the piston rod end after having made the out-stroke returns during the in-stroke along a portion of the groove inclined in an opposite direction to that traversed during the out-stroke, and the rotation of the shaft is thus continued in the same direction. An obvious and serious objection to this plan is the great friction of the piston rod ends upon the sides of the grooves, which must occasion not only loss of power but also rapid wear. It has also been proposed to make use of a ball-and-socket or universal joint fitted with arms for the pistons and an arm for the crank of the shaft, the motion of the joint being similar to that of the disc in the disc engine, and being communicated to the shaft in the same way.

In the engine described in the present paper, the steam cylinders are placed with their axes parallel to the propeller shaft, and the reciprocating motion of the pistons is made to cause the rotation of the shaft in as direct and simple a manner as in any other direct-action engine.

The engine is shown in Figs. 1 and 2, Plate 72.

Fig. 1 is a longitudinal section of the engine, taken at an inclination of 45°, passing through one of the steam cylinders, the propeller shaft, and the air pump of the other cylinder.

Fig. 2 is an end elevation of the engine, with the shaft and vessel in section.

The shaft A is made with a crank B, which is turned by means of a lever piece C, corresponding to the ordinary connecting rod, and moved by the pistons D through the intervention of connecting rods E, which are little more than ordinary piston rods, contrived to allow of the very slight lateral movement required by the peculiar arrangement of the parts.

The chief peculiarity of this arrangement is in the form of the shaft A. This shaft has two arms FF forged upon it, nearly at right angles to its axis; and the elongated journal B, or portion of the shaft which lies between the arms F and connects them, is inclined to and crosses the axis of the shaft, so that the arms stand out from diametrically opposite points of the shaft, the whole being termed a Z crank, from its zigzag form. The crank B serves for both cylinders GG and both air pumps HH, and would serve for several more cylinders, if these were arranged round the line of the shaft A, either along with or opposite to the cylinders shown; it is forged in a single solid piece, and is obviously much less costly than a shaft with two double cranks at right angles to each other, such as is required for any ordinary arrangement of engines.

Upon the inclined journal of the crank B is placed the lever piece C, consisting of an elongated tubular boss fitted with brasses to work loosely upon the journal, and having four arms or levers standing out at right angles to the journal and to each other. The lever piece C is cast or forged in two halves, which are bolted together upon the journal of the crank by strong flanges. The two upper and longer arms I I are connected by ball-and-socket joints to the connecting rods E of the two steam cylinders, whilst the lower and shorter arms KK are similarly jointed to the connecting rods L of the air pumps H. The pistons of the steam cylinders and air pumps are fitted with small trunks to allow of the very slight lateral movements of the connecting rods, which are jointed to the pistons by ball-and-socket joints. The crank B is prevented from carrying the lever piece C bodily round by means of a stud M projecting downwards from the lever piece, the lower end of the stud being inserted loose in a slide block working in the segmental grooved guide N. Another contrivance for the same purpose consists of a semicircular bow or half gimbal ring, the ends of which are jointed upon horizontal studs projecting laterally from the lever piece at the level of its centre, the bow turning about a fixed vertical axis below the lever piece.

In explaining the peculiar but simple motion involved in this engine, let the crank B be supposed to be in the position represented in the figures, inclined at an angle of 45°. In this position the crank is turned up towards the starboard or right hand cylinder, and the right arm of the lever piece is therefore as close as it can go to that cylinder, the piston being at the inner end of its stroke. As regards the port or left hand cylinder the crank B lies in a plane at right angles to that passing through the shaft and through the axis of the port cylinder, and the left arm stands at right angles to the shaft, the piston being exactly at half stroke. In this position if steam is admitted to drive the port or left hand piston outwards, this piston will have full power on the crank, the lever piece acting as a bell crank lever to turn the crank B. As soon as the steam enters behind the starboard or right hand piston, it begins to help the other, and when a quarter of a revolution has been made, the port piston will be at the end of its outward stroke, the starboard piston will be at half stroke, and the crank will be in exactly the same position with regard to the starboard piston as it was in with regard to the port piston at first, the starboard piston now having full power on the crank to continue the revolution. Then as the starboard piston comes towards the end of its outward stroke the port piston will be returning, and will bring round the crank, which will have passed its dead centre as regards the port piston. The motion of the two pistons is thus combined, one being at the most effective part of its stroke whilst the other is on the dead centre, as in common engines where two steam pistons are connected to cranks at right angles to each other.

The rotation of the crank causes the arms of the lever piece to reciprocate longitudinally, and the lower arms K consequently work the air pump pistons in and out. As these arms are scarcely more than half the length of the upper arms I, the stroke of the air pump pistons is considerably less than that of the steam pistons, so that the air pumps have the advantage of a comparatively low speed.

The arrangement of these engines is very convenient, the steam cylinders being placed upon the tops of the condensers and above the air pumps, whilst the whole is combined together into a simple and compact framing. The shaft A is carried in a strong outer pedestal bearing O, which is represented as constructed to receive the thrust of the propeller; it is connected to the condensers by a sole plate and to the cylinders by two strong stays. The other end of the shaft is carried in bearings between the cylinders and air pumps, and projects slightly beyond the cylinders to carry eccentrics P for working the valves and feed and bilge pumps. The valves and feed and bilge pumps may be arranged and worked in various ways, and the engineer may place these minor details where he likes, as the design of the engine affords peculiar facilities for communicating the requisite motion in any way that may be desired.

The crank and lever piece form the principal features of the design, the other details being susceptible of considerable modification. Thus three or more steam cylinders may be placed round the shaft, or the power of the engines may be doubled at the expense of only half as much space in addition, by placing another set of cylinders, condensers, and air pumps directly opposite to those shown in the drawings, and working upon the same lever piece from the opposite end. Or the steam cylinders may be of different sizes, so as to act on the combined high pressure and condensing system. For auxiliary power in steamers of large size the two steam cylinders may be placed below the shaft, in the place of the air pumps in the arrangement shown, the air pumps being placed opposite to them, and facing the other end of the lever piece. For small high pressure engines three small cylinders may be placed equidistantly round the shaft, so as to work upon a three-armed lever piece; and it may be mentioned that with such an arrangement the action of the three pistons would be so nicely combined that there would be scarcely any end thrust on the shaft from the action of the pistons.

The propeller shaft may be continued in either direction from the engine, and the crank being of such a strong form, the thrust of the propeller may be received through it and on the extreme end of the shaft if desired. The shaft is low down, and on account of the peculiar form of the space taken up the engine can be placed as far aft in the vessel as is convenient; or if the engine is placed at the wider part of the vessel, sufficient space for coal bunkers will then be left between it and the sides of the vessel. Whilst however the compactness of this arrangement is very great, this quality is not accompanied by any complexity of parts or other defect; there is no part about the engine requiring attention, or at all likely to need repairs, which cannot be got at with the greatest facility.

The motion of the pistons is in the direction of the ship's length, thereby completely avoiding the transverse or vertical tremor and vibration caused by ordinary screw engines. The shaft is self-balanced, owing to the peculiar form of the crank, and can consequently be driven at a higher speed than on the common construction, in which the heavy unbalanced cranks make the motion irregular, and the whole arrangement of the engine is such as to reduce the vibration of the moving parts to a minimum.

In conclusion, the following practical results may be mentioned, although it must be admitted that they are upon a diminutive scale. In the working model exhibited, there are two cylinders of 2¼ inches diameter and 1½ inch stroke; and with a steam pressure of 30 lbs. per square inch in the boiler, a speed of 1800 revolutions per minute has been attained, and counted by the counting mechanism of a meter. This speed is equal to an average velocity of the pistons of 450 feet per minute, and shows at all events the practicability of the contrivance.

M. Hunt showed a working model of the engine, which was driven by steam after the meeting.

The Chairman enquired whether the motion was pretty steady when driven at a high speed.

Mr. Hunt said that the engine had been found very steady at all speeds, and the higher the speed the steadier the motion appeared to be, without any tendency to oscillation. There had not been any engine constructed at present on the proposed plan, except the working model exhibited, which however had been driven for some time at a very high velocity.

Mr. Harvey remarked that the engine certainly occupied a very small space, and was an ingenious and effective application of the plan; but he thought the construction would be expensive, and would cost more per horse power than oscillating engines. The lever piece if of wrought iron would be expensive, and it would require to be very heavy if of cast iron.

Mr. Hunt said that the comparative cost of construction must from the novelty of the design be a matter of opinion until decided by actual trial.

Mr. Dunn suggested that the lever piece would be best made of strong gun-metal, which would avoid the expense of forging it into shape.

Mr. Morrison thought there would be a great longitudinal thrust upon the shaft, from the longitudinal position of the cylinders, and greater friction of the crank than in the ordinary engines.

Mr. Hunt said that the thrusts of the two pistons partly counteracted each other, leaving only a slight longitudinal thrust on the shaft; and with three pistons they would be completely balanced, with no longitudinal thrust upon the shaft from the engines.

A vote of thanks was passed to Mr. Hunt for his paper and the working model exhibited.

The following Paper, by Mr. John Downie, of Glasgow, was then read:—

DESCRIPTION OF AN IRON CONSTRUCTION OF FOUNDRY, AND AN IMPROVED PROCESS OF MOULDING PIPES AND HOLLOW CAST WARE.

The subject of the present paper is an improved application of iron to structural purposes, where great lateral strains, such as are occasioned by the action of powerful lifting cranes, have to be resisted; which has been carried out in the construction of the North Woodside Iron Works, erected by the writer in 1852.

The large moulding shop of these works is shown in Figs. 1 and 2, Plate 73; Fig. 1 is a longitudinal section along one half of the foundry, and Fig. 2 a general plan of that portion of the works, showing the framing of the roof and the position of the cranes, moulding pits, and stoves, &c. The foundry is constructed wholly of iron, with the exception of the horizontal timber framing for the tops of the cranes. The separate parts of which it is composed are arranged and united together in such a manner as to resist lateral strains in all directions, and the thrust of the cranes is carried down to the ground by a series of sloping struts at the sides and ends of the foundry.

The construction of the foundry is shown to a larger scale in Figs. 3 and 4, Plate 73, Fig. 3 being a transverse section of half the shop, and Fig. 4 a corresponding plan.

The columns A support the longitudinal girders BB, the ends of which form sockets to receive the ends of the transverse timbers C. The girders B are connected outside to the struts D by a dovetail joint and bolts, and the struts thus serve to bind the girders together while they receive the pull or thrust of the strains to which the building is subjected. The foundations for the columns and struts are cubes of brickwork E, well grouted and bound together with top and bottom plates and tie bolts, the earth around them being well rammed and secured. By this arrangement the heavy strains of the cranes are carried down into the ground and distributed over a large area, giving great stability and strength with very little proportionate expenditure of material.

The junction of the columns, girders, and struts, is shown in detail in Figs. 5 to 11, Plate 75. The columns A, Fig. 7, are cast with a snug or projecting piece F on the top, in the shape of a T head, Figs. 7 and 9, which forms a strong connection between the girders B and the column, and locks them securely together. The flanges G on each girder form a socket to receive the end of the transverse timber C, and the outer corners receive the ends of the diagonals HH. The girders are bolted together by a cross bolt through the transverse beam, and the latter is secured to the top of the column by a vertical bolt. The under side of the beam is notched out to fit upon the head of the snug F, which thus serves as a tenon to take the strain off the cross bolt when the beam is subjected to a pull. The strut D is cast with a dovetail jaw I at the upper end, Figs. 5 and 6, which grasps corresponding dovetail pieces cast on each end of the girders B; the dovetail joint serves to bind the girders together, and also takes the pull of the cranes down to the foundations. The thrust is received by the strut by means of the palm K, Fig. 7; and the struts, girders, and columns are thus united firmly and securely, in such a manner as to offer an effective resistance to all the strains occasioned by the work of the foundry without any injury or distortion of the frame-work of the building, which is farther strengthened in the longitudinal direction by corner brackets bolted to the columns and girders, as shown in Fig. 1. The upper roof is entirely independent of the rest of the frame-work of the foundry, and takes no part of the strains. The main principals L rest on the top of the transverse timbers C, immediately over the columns A, and abut against the girders B, so that the thrust is received by the struts D and thrown upon the foundations in the ground, thus obviating the necessity for tie rods to prevent spreading.

The work of the foundry is carried on by means of a set of swing cranes, the larger of which are in the centre of the foundry, and the smaller fixed to the side columns. The large cranes are supported at the top by a step or socket M, Figs. 3 and 4, fixed on the transverse timbers C, consisting of a bearing cast with sockets on the upper side to receive the longitudinal timbers N and the diagonals H. Similar socket pieces O are employed at the intermediate junctions of the longitudinal and transverse timbers. In the present arrangement accordingly the longitudinal and diagonal beams are supported in their entire depth by the transverse beams, and a good abutment is obtained for the ends in the sockets, instead of the ordinary method of slightly notching the longitudinal timbers on the transverse ones, and then bolting them together. The smaller cranes are principally derrick cranes, working about the alternate columns of the foundry.

The distance between the columns and roof principals is 21 feet, and the width between the two rows of columns 42 feet, with a clear height of 21 feet under the transverse beams. By taking advantage of the sloping struts to form side lean-to roofs, an increased width of foundry is obtained, bounded by the dwarf side walls P, at which the roofing terminates; an uninterrupted floor space of 84 feet total width between the dwarf side walls is thereby left available, a desideratum of much importance in such arrangements.

The upper roofing consists of sheets of corrugated iron, supported on iron purlins carried by the roof principals L. Ample ventilation is secured at the eaves through the girders B, which are cast with a series of openings for the purpose, and also by the top opening running the entire length of the roof, and the openings left at the overlap of the roof sheets. The foundry is lighted entirely from the side roofs with Hartley's rough sheet glass, fixed in metal sash bars which rest on purlins carried by the struts; the skylight runs nearly the whole length of the roof, so as to give a flood of light direct upon the moulding floor.

Since the erection of the works in 1852 this construction of foundry has been found to meet all requirements of resistance and strength, without any apparent giving in any of its parts, although during the period that has since elapsed it has been subjected occasionally to strains of between 45 and 50 tons on the cranes; and the result has thus proved satisfactorily that iron may be successfully applied in preference to any other materials in erections where great strength and power of resistance are required.

The farther subject of the present paper is a description of an improved process adopted by the writer for moulding pipes and hollow case ware, and applicable to a wide range of articles, such as cast iron socket pipes for gas or water, rain water conducting pipes, camp ovens, kettles, three-legged pots, shot, shell, guns, mortars, and articles generally of cylindrical or spherical form.

The internal pattern is made separately in core boxes or otherwise in the ordinary manner; but the pattern for producing the external portions of the mould is fitted with a cam, in the form of a collar, resting upon adjustable bearings in the frame work of the table on which the moulding flasks are rammed; a portion of the cam is concentric with the axis of the pattern, and the remainder eccentric, so as to elevate the pattern between the two edges of the moulding table and withdraw it again accurately by lowering

The apparatus employed for this purpose is shown in Figs. 12 to 15, Plate 75, which represent it as arranged for moulding a 28 inch socket pipe.

The moulding table R has the two edges SS of its face, shown dotted, shaped so as exactly to fit the pattern T when the latter is raised with its axis level with the edges S, as in Fig. 14. The pattern is fitted with a cam or collar U at each end, of which the portion from V to X is concentric with the axis of the pattern, and the remainder eccentric. The cam U rests upon the adjustable bearing Y, and the axis of the pattern is guided by vertical slots in the ends of the moulding table. On causing the pattern to rotate, the eccentric portion of the cam acting on the bearing Y gradually raises the pattern till it bears on the point V of the cam, when the pattern is in its highest position with its centre line level with the edges S of the moulding table, as in Fig. 14. The flask Z is then placed on the table and rammed up to form one half of the mould, and the two faces SS of the table form the "parting surface" of the mould, being made fair for this purpose by planing, turning, or other means. The farther rotation of the pattern upon the concentric portion of the cam from V to X retains it in contact with the mould, and thus sleeks, smoothes, or finishes the mould, until on reaching the point X the pattern is gradually withdrawn, as in Fig. 15; the flask Z may then be removed without danger of injury to the parting or junction surface, ready for closing and casting in the usual manner.

The same principle has been adopted also for making the cores or internal moulds, by employing a core barrel made in three portions, two of which are hinged upon the third; the centre spindle is fitted with cams of the form above described, which act upon a V piece inserted between the two free edges of the core barrel. By turning the centre spindle the V piece is pushed out or drawn in, thereby expanding the core barrel or contracting it as required; by this means the use of straw or hay in core making is dispensed with.

By applying this method to moulding three-legged pots and other articles of that description, when the several pieces of the mould are put together, "cheeks" such as are commonly required in the ordinary plans of moulding such articles, for protecting the partings of the moulds, are by the present plan entirely dispensed with, and the ugly scar left by them on the casting is avoided; and instead of the flasks being required in four pieces to form the mould, three are sufficient, the external mould being made in two halves with plugs inserted for the legs. Consequently several sizes of pots may be made with the same sized flasks; and while the plant is otherwise simplified and reduced in cost, increased efficiency is obtained, since by this arrangement little or no discretionary power is left in the hands of the workman. Skilled labour is rendered less necessary, as the mould receives the requisite finishing before leaving the machine, and the results are increased production, fewer waster castings, and a better quality of work at less cost for labour.

Mr. DOWNIE exhibited a half sized model showing the mode of forming the junction between the girders, columns, roof principals, and struts.

The CHAIRMAN asked how many cranes were fixed in the building that had been described.

Mr. DOWNIE replied that 17 cranes had been put up in the foundry, and the greatest weight that had been lifted at once by one crane was about 45 tons, the other cranes doing their ordinary work at the same time.

Mr. FAIRBAIRN enquired how the longitudinal and diagonal staying of the roof framing was managed, so as to resist the severe thrust of the heavy cranes in the different directions.

Mr. DOWNIE explained that the present construction of upper roof framing required no diagonal stays or tie rods, the thrust of the principals and cranes being carried down the sloping struts to the ground foundations, so that each portion was directly supported and stayed from the ground.

Mr. FAIRBAIRN observed that the whole building was in fact like a tent without walls, carried down to the ground on all sides. It was certainly an ingenious and economical arrangement, well adapted for situations where land was cheap, but not so admissible where land was dear, from the greater extent of ground covered for the same accommodation within the building.

The CHAIRMAN enquired what was the position in which the cupolas were placed in the foundry.

Mr. DOWNIE said that the reverberatory air furnace and two large cupolas were placed in the internal angle of the building, each within the range of two cranes, and all the cranes communicated with one another through the intermediate ones, two other smaller cupolas being placed at the side.

Mr. FENTON asked what extent of the roof was available as a working shop.

Mr. DOWNIE stated that the foundry for heavy work was 84 feet wide, clear between the dwarf side walls, and being right angled was

168 feet long each way; the foundry for light work was a continuation of the same roofing, and the whole area under cover was about 1¼ acres, or 60,000 square feet effective moulding floor room.

Mr. Beyer enquired what was the size of the centre part of the building, and what was the whole cost per square yard upon the ground covered.

Mr. Downie replied that 30s. per square yard was the average cost of the whole building divided by the area enclosed within the walls. The centre portion swept by the cranes was 42 feet width between the two rows of pillars and 21 feet height clear under the transverse beams.

Mr. Morrison enquired why travelling cranes were not used instead of the radiating cranes shown in the drawing; there was some objection at first on the part of the men against travelling cranes, because the men placed aloft suffered the inconvenience of the steam rising from the hot sand; but his own experience had led him to consider travelling cranes more convenient and economical for working a foundry, and in the construction of foundry now described they would do away with the necessity for the outer struts.

Mr. Downie said that if two or three travelling cranes were used they would interfere much with one another during the process of casting, and it would be impracticable to get through such large quantities of work as with swing cranes. He accordingly preferred radiating cranes for foundry purposes, although for other work, such as in erecting shops, the former might be preferable. The radiating cranes were more readily and quickly shifted than travelling cranes, and none of the men were required aloft, but all remained below, ready to help at any time in the work going on. On these accounts he had been led by his own experience decidedly to prefer swing cranes to travelling cranes for working a foundry.

Mr. Morrison thought an important objection to swing cranes was that they wasted so much room, causing inconvenience often in extra shifting of the moulds to make room. If a travelling crane were at one end of the foundry it could carry the metal the whole length of the foundry direct, but with swing cranes this could be done only by changing from one to another. In his own foundry, which was 45 feet wide, a single travelling crane was used running the whole length, and served the foundry very conveniently. It was worked by two men, who could come down by a ladder when wanted, but they usually remained aloft, as they were so constantly required there. The crane was constructed with two 14 inch beams of Memel timber, and managed a 15 ton casting readily, or about 22 tons total weight including sand and boxes.

The Chairman observed there was certainly an advantage in having the men all ready below in a foundry, where their help might be required at any moment. If a travelling crane were worked by hand power the men were required to be aloft pretty constantly, whether wanted or not, so as to be ready without delay.

Mr. McFarlane decidedly preferred travelling cranes for foundry purposes where a regular run of the same class of castings was made, such as pipes, &c.; but there was no occasion to have the men aloft, especially for the lighter description of castings; he had a travelling crane worked entirely from below by a winch and chain, over a width of 20 to 25 feet; two men could travel the crane with a weight of from 2 to 3 tons. Where much shifting however was required, swing cranes might be advantageously used.

Mr. Downie thought that the advantage that had been named of a travelling crane carrying metal the whole length of the foundry would not be found to exist in practice, as a great number of workmen must necessarily be kept waiting till it was disengaged, and where large quantities were melted this would amount to a serious loss. With the swing cranes the passage of the metal was the work of only a minute or two, and then the cranes were at the service of the intermediate workmen, with scarcely any delay from waiting. At the London Works, Renfrew, in that neighbourhood, travelling cranes had given place to swing cranes, and he believed for the same reasons.

Mr. Harvey thought it was an important question whether steam or hand power were the cheapest and most suitable for working foundry cranes. He remembered that at Mr. Neilson's Hyde Park Foundry, where there was a set of swing cranes, 12 feet long, lifting 4½ tons each, a trial was made of the comparative advantage of steam and hand power, and it was found that in casting large pipes by hand labour 6 men working 2 hours were required for casting each pipe. A steam cylinder of 5 inches diameter and 12 inches stroke was then applied to one of the cranes, to lift the metal and pour it into the mould, and 35 minutes only were then required for the casting, including drawing the core bar. Four steam cranes were set to work at first at the end of the foundry where there were the largest weights to be lifted, and were found to answer so well that steam power was applied to all the cranes in the foundry except some of small size.

The steam pipe was carried through the foundry like a gas or water pipe, and by turning on the steam the cranes were put in motion as easily as by hand labour, and were completely under control. Great economy of time was thus effected, and saving in the amount of labour required in the foundry.

Mr. DOWNIE said that he had found hand labour sufficient, and considered it safer for the moulds and chains, &c.; he thought it more economical for his work than steam power, though it might be otherwise in the case of a different class of work, such as had been referred to, where the cranes would be kept almost constantly in motion.

Mr. McFARLANE was not aware whether steam power was preferable for general jobbing work; he feared it would scarcely be manageable enough; it was more applicable for moulding purposes where a large run of the same kind of goods was required.

Mr. E. JONES thought there was more perfect control over the crane with steam power than with men, and steam was more thoroughly under command for instant application when required. He understood there was a foundry in that neighbourhood where the application of steam power was carried out so completely as to dispense with men for moulding as well as casting, producing greater accuracy as well as economy of work.

Mr. FOTHERGILL observed that much time was unavoidably lost in calling the men together in a foundry, when the power was wanted to be suddenly concentrated for a particular purpose; but with steam power there was the great advantage of the whole power being instantly available at all times.

The CHAIRMAN said that for general purposes he decidedly preferred steam power for working cranes, and in his own erecting shop had found great advantage in working both radial and travelling cranes by steam power. A shop of 45 feet span had a travelling crane running the entire length, and driven by a shaft 100 feet long with a groove in it, which communicated motion to the various parts. Four radial cranes were also employed, the travelling crane working over them.

He proposed a vote of thanks to Mr. Downie for his paper, which was passed.

The following Paper, by Mr. E. D. Chattaway, of Edinburgh, was then read:—

DESCRIPTION OF A CENTRAL BUFFING AND DRAWING APPARATUS FOR RAILWAY CARRIAGES.

The frequency of accidents arising from the insufficiency or defective nature of railway couplings, more especially those of the wagon stock, induced the writer to endeavour to discover some simple and inexpensive means of remedying so serious an evil; and he was led to the conclusion that a new form of coupling combined with a centre buffer was the only effectual mode of accomplishing the desired end. He accordingly adopted the arrangement described in the present paper, the principle of which is a combination of the whole buffing coupling and drawing mechanism upon one central rod, thereby dispensing with the use of separate corner buffers and side chains.

The central buffing and drawing apparatus is shown in Figs. 1, 2, and 3, Plate 76.

Fig. 1 is a side elevation, and Fig. 2 a plan of the new coupling working in connection with an ordinary drawhook; and Fig. 3 is an end view of the buffer head.

The buffer and drawhook are constructed in one piece, and the buffer head A instead of being circular is made of the peculiar form shown in Fig. 3. The lower portion only is curvilinear, and the upper part is made narrow, and, while presenting a buffing surface in front, is shaped on its inner side similar to a drawhook, for the purpose of receiving the coupling link B, which works upon it as upon an ordinary drawhook, and thus forms a complete hook and link connection. The draw rod C is screwed near the end just within the buffer head. Upon this screwed part is fitted the adjusting nut and collar D with projecting arms E, Fig. 2, carrying the large coupling link B. The coupling can thus be drawn hard up or slackened off by means of the pendulous lever F, as occasion may require.

It will be seen from this description that the apparatus is simple in its details, and consequently inexpensive and not liable to get out of order.

The ordinary coupling and buffing arrangements as applied to railway wagons are open to several objections. As there is no means of tightening up the couplings, there is always a considerable amount of play between the adjacent vehicles in a train, frequently as much as 18 inches in wagons. The effect of this is, in the first place, to lengthen the train, thereby causing a greater expenditure of motive power, owing to increased effect of the wind and pressure of the flanges of the wheels against the rails when running through sharp curves; and in the second place, to render the couplings liable to break or to become detached from the drawhooks, in consequence of the train being started and stopped in detail by a series of sudden and violent jerks; this jerking action also causes a severe strain upon the draw springs and often breaks them, besides acting injuriously upon the permanent way and increasing the risk of conveying goods of a fragile nature. As regards corner buffers they are objectionable from the circumstance of the two buffers being seldom struck at the same instant or with the same degree of force, even on a perfectly straight line, while on curves the buffing action is mainly confined to one side of the train, severely straining the framing of the vehicles and having a tendency to force the tenons out of the mortices. Besides tending to damage the rolling stock, this action also tends to injure the permanent way, and to increase the cost of maintenance of both. It is also to be remarked that the ordinary buffers and couplings are always opposed to instead of being in harmony with each other, the couplings being slackened as the buffers are brought into play, and vice versâ; and the reaction of the buffers has sometimes fractured the couplings. A fatal accident from this cause has come within the personal knowledge of the writer.

A farther objection to the ordinary couplings is the difficulty and delay frequently experienced in attaching and detaching wagons, since unless the couplings be slack it requires a violent shunting together of the train to allow the coupling link to be slipped over the drawhook; and if the drawhooks be close to each other before the coupling has been lifted up, the train has to be drawn apart to admit of the link being raised, and then shunted together again in order to be attached. Independent of the extra expenditure of engine power and wear and tear of rolling stock occasioned by this shunting, it is also a fruitful source of accident, as it appears that no fewer than ten persons were killed and eight injured during the last year by being crushed between the buffers while engaged in coupling carriages and wagons.

It is submitted that by the adoption of the central buffing and coupling apparatus now described these objections will be obviated, as the apparatus presents the following advantages :—

Firstly, economy of cost and simplicity of construction, the cost being less than two thirds that of the corner buffer arrangement; the parts are few, easily fitted together, and not liable to get out of order.

Secondly, facility of coupling and uncoupling; it requires no sudden shunting of the train together to slip the coupling over the drawhook, since the coupling link is attached to a collar moving freely round the drawbar, and can thus be raised and attached even when the buffer head is in contact with the drawhook.

Thirdly, saving in dead weight; the new coupling is upwards of 5½ cwt. per wagon less than the average weight of the ordinary buffing and coupling apparatus; this in a train of 30 wagons gives a saving of dead weight equal to 8¼ tons. Taking the cost of hauling one ton at ·20*d.* per mile, the money saving averages 1·65*d.* per train mile; or assuming the average daily mileage of a train to be 120 miles, the daily saving is 16*s.* 6*d.* per train, equivalent to the wages of the engineman, fireman, and guard.

Fourthly, the reduction in wear and tear of wagons, by lessening the amount of shunting and the sudden jerking of the wagons. Also the buffers being in the centre of the wagon or carriage are always practically in the same straight line, and receive the whole force of the shock when the train collapses, thus relieving the train from the severe strain to which it is subjected when corner buffers are used.

Fifthly, the non-liability of this apparatus to break away or become uncoupled, the parts being few, simple, and made of suitable strength, and the couplings being drawn tight up.

Sixthly, economy of motive power and cost of maintaining the permanent way. The centre buffers and couplings do not require so much space between each wagon as the ordinary buffers. They also save space by the .couplings being screwed tight up, the present wagon couplings having from 6 to 18 inches play. Taking the saving of space between each wagon at 14 inches, this will amount to a total saving in length of 35 feet in a train of 30 wagons. Farther, the buffing action being in one continuous line at the centre of the carriages or wagons, there is little tendency to any transverse action or pressing of the flanges of the wheels against the rails while passing round curves, as is the case with the corner buffing system, which causes a considerable loss of engine power and acts injuriously upon the permanent way. The writer believes that the general experience of working railways corroborates the opinion that a long train takes more power per ton to drag it along than a short one.

The centre buffing and coupling apparatus has been applied to two of the mineral wagons running on the North British Railway, with a view of determining the practicability of using it conveniently in connection with the ordinary buffers and couplings. These wagons have been running for nearly five months upon one of the coal branches have a gradient of 1 in 25 with curves of 300 feet radius, and the result has been to establish decisively the feasibility of the centre buffers working satisfactorily amongst stock with corner buffers. Arrangements are now being made for the more extended use of the centre buffer in consequence of the success of this experiment.

It may be observed in conclusion that the centre buffer and coupling being economical in first cost and sound in principle is well adapted for introduction in our colonial railways and for application to cattle, coke, and mineral wagons, many of which have at present no spring buffers; and that it forms a convenient coupling for tenders, relieving the framing of the engine from injurious strains when shunting.

Mr. Chattaway showed a full-size specimen of the central buffer and coupling, as applied to a railway carriage.

Mr. Dunn observed that the Dublin and Kingstown line had been worked with centre buffers on the carriages for many years after first starting, and the same plan had been adopted also on some of the engines.

Mr. Fenton said that the plan referred to was different from the one now described, and not suitable for joining with rolling stock of the ordinary description.

Mr. Chattaway understood that the central buffers on the Dublin line had worked quite satisfactorily, but had been recently altered to side buffers, because of joining another line having side buffers, as the central buffers that had been in use could not be adapted to work with side buffers.

Mr. H. Robertson thought there was one primary objection to the new arrangement, that in buffing the blow would not be received by the strongest part of the frame. In the present construction of stock with side buffers this was provided for, as the whole of the sides of the wagon as well as the frame presented a resistance to the shock of buffing.

Mr. Chattaway thought the difficulty would be surmounted by making the centre draw bar serve as the buffer rod, the draw bar running continuously through the frames of the carriages, so as to convey the shock from the extreme carriages through direct from one carriage to another, without acting upon the frames of the intermediate carriages.

Mr. Tosh remarked that the framing would have to be very strong to withstand the action of the whole buffing strain in the centre instead of receiving it directly on the ends of the main longitudinal timbers as in the ordinary arrangement; and a different arrangement of the frame would be necessary wherever the new plan was to be adopted. The proposed arrangement did not appear sufficiently strong to stand shunting with a powerful engine; and in the case of two of the new buffer heads coming together in a train, the coupling link would rest on the top of the draw bar out of the horizontal line of traction, which would have a great tendency to bend the draw bar, and would throw more weight upon one pair of wheels than the other. He did not see that there could be any economy in the springs, &c., as their strength must be doubled to retain the same resistance as was given by the ordinary plan of two buffers.

Mr. Morrison had seen the working of the centre buffing apparatus that had been tried on the North British Railway, but thought it would interfere with safety, the pull in drawing was on the top part of the coupling hook, but the buffing was received on the bottom, and this action had a great tendency to break the hook off. He understood that in a tender to which the centre buffer had been applied it had been found necessary to strengthen the frame by putting in two longitudinal beams in the centre.

Mr. Fenton observed that there would be a difficulty in starting a heavy goods train if the couplings were all tight up, as it frequently happened that the train could be moved only by starting one wagon at a time, and not the whole train at once.

Professor **Rankine** thought it must always be requisite to provide for slack couplings between the wagons, as a heavy train of wagons had to be started one at a time, in order to overcome the inertia of the wagons.

Mr. **Harvey** remarked that an objection had been made to having the couplings slack between the wagons of a train, as they were liable to be broken by the sudden snatch of the engine in starting; but this might be prevented by applying the power more gradually. He had some years since designed a balanced regulating valve for a large locomotive engine, to remove the complaint of breaking the couplings, by causing a very gradual admission of steam through a V shaped port with a compound lever, to give a very small opening of the valve at first by a long motion of the handle.

A vote of thanks was passed to Mr. Chattaway for his paper and for the specimen exhibited.

The following Paper, by Mr. Robert Harvey, of Glasgow, was then read :—

DESCRIPTION OF AN IMPROVED SUGAR EVAPORATING APPARATUS.

In concentrating cane juice, after it has been expressed by the cane mill, a variety of processes have been adopted; the apparatus most generally in use is called the "Battery," and consists of five or six pans all placed in a line, each less than the preceding one in the proportion that the liquor is concentrated. The liquor is first put into the largest pan, and ladled from one to another successively till its arrival at the last, called the "finishing teache," in which the sugar is brought to the required density. It is thence taken to the curing house where it is placed in suitable vessels for allowing the complete drainage of all the molasses or uncrystallizable portion, a large part of which however can be rendered into sugar by reboiling, which is mostly effected in refineries in this country.

In the battery process the greatest danger arises near the termination of the boiling in the teaches, under which the fire is immediately placed. The density to which the sugar has been brought renders carbonization difficult to be avoided at this stage of the process, and great care is necessary in the management of the fire.

To meet these difficulties, the improved apparatus described in the present paper has been invented, by which the requisite degree of concentration can be arrived at, without the possibility of applying a temperature injuriously high.

The "Bour" pan, named after the inventor, and now successfully in operation in many of our sugar-growing colonies, is shown in Figs. 1, 2, and 3, Plate 77. It consists of a series of thin hollow discs of copper A A, securely fixed upon a central axis B. The discs are heated and maintained at a uniform temperature by steam, which enters at one end through the hollow axis B. A section of the axis is a cross, Fig. 3, the edge of each portion having a flange set to one side, forming longitudinal grooves, the use of which is to retain the condensed water from the steam, and deliver it at the extreme end of the axis. The axis is about 9 feet long, and has fitted upon it 10 hollow discs A A, 3 feet in diameter. In the inside of each disc are two spoons C, fixed to one side of the disc, and running from the centre to the circumference; these collect the water of condensation from the steam, and terminate in tubes, delivering the water into the longitudinal grooves in the axis B. On the outside of the discs are a series of small buckets D, which lift the liquor as the discs move round, and being open at the sides allow a quantity of it to be distributed in a thin equable film over the entire portion of the surface of each disc that is not immersed in the liquid. This is a feature in the machine that is peculiarly favourable to the liberation of water from the liquor undergoing concentration, when it approaches the density necessary for finish. The axis B is mounted on a frame E carrying a flat shallow pan F, the bottom of which is curved to a radius about 1½ inch longer than that of the discs; into this pan the cane juice is put, after having been evaporated in open pans to 28° or 30° Baume. When the concentration has been carried to the required degree, the remaining liquor is run out of the pan by a valve and pipe G.

The discs are made to revolve about 10 times per minute and are driven by a strap and pulley H on the axis B. The exhaust steam from a high pressure engine is made to enter at one end of the hollow axis at 2 lbs. per square inch pressure above the atmosphere, and the large amount of heating surface which the discs expose for the steam to act upon is the source of the efficiency of the apparatus as an evaporator. The low temperature under which the process is effected, the liquor never exceeding 170° Fahr., renders it peculiarly adapted for the colonies, where skilled labour is very expensive, and in many places cannot be had.

The adoption of the Bour pan supersedes the use of the teache in the battery, and the granulation of the sugar is finished at a much lower temperature than by the teache, thereby avoiding any tendency to carbonization of the sugar. An apparatus designed for the same object has been previously introduced under the name of the "Wetzel" pan, so called from its inventor. A side elevation of this apparatus is shown in Fig. 4. It consists of two hollow discs I I connected by a number of horizontal tubes K; steam is admitted to one of the discs through the hollow axis, and passes through the tubes to the other disc, in which the water of condensation collects and is carried off through the axis at that end. In the use of the Wetzel pan it was found that the crystallization of the sugar is most perfect at the two end discs; and this circumstance led to the adoption in the Bour pan of a series of discs in place of the tubes, whereby the whole apparatus now produces the superior crystals that were previously obtained only from the two end discs.

A trial made recently with one of the Bour pans on the premises of the manufacturers, Messrs. D. Cook & Co., of Glasgow, proved highly satisfactory; the pan was used to concentrate a hogshead of molasses weighing about 9 cwt., which was boiled to the proper density in 20 minutes. This experiment was made in the presence of several planters and other gentlemen interested in the colonies, and appeared to afford full satisfaction; the sugar produced was considered by refiners equal to that produced in the vacuum pan from the same materials.

Mr. HARVEY showed a model of the apparatus, with a sectional model showing the construction of the discs and the grooved shaft. He said the Bour pan was considered a great improvement on the previous Wetzel pan, in which the two end discs were connected together by 26 tubes of 2 inches diameter; this had been invented for the same object of preventing the risk of over-heating the sugar in evaporating, without requiring a vacuum pan, which was objectionable from the expense and difficulty of repair in such situations as the colonies. The inventor of the new apparatus, M. Bour, was a large manufacturer of Wetzel's pans in Mauritius; and having observed that the crystals were uniformly the largest and best on the end discs, it occurred to him that a series of discs would give the same improved effect over the whole surface as was obtained in the end discs, and from the vertical position of the disc surfaces the liquor would be disposed in a thin equable film, peculiarly favourable to rapid evaporation. The accumulation of water in the discs, consequent on the large condensation of steam was caught up by spoons and delivered into the grooves of the shaft, whereby a continuous drainage was effected out at the open end of the hollow shaft. A very low temperature was a great advantage in the manufacture of sugar, and the commercial value of the result was thereby much increased, the greater part of the syrup being converted into good crystallized sugar, instead of a considerable portion being reduced to uncrystallizable molasses by exposure to too great heat in the process of evaporation. The exhaust steam used for heating the apparatus was at a pressure of only 2 lbs. per square inch, the pressure being limited by an escape valve at the entrance; the plan was very simple, and had been found to effect the complete evaporation of the sugar very perfectly, without impeding the working of the engine or causing any increase in the quantity of fuel.

Mr. James Johnstone said the rapid evaporation of the syrup at a low temperature was a point of great importance in the manufacture of sugar, and he had spent much time and money on that subject.

The principle of surface evaporation, on which the apparatus described in the paper acted, was he believed first introduced in the construction of evaporating apparatus by Mr. Cleland of Glasgow, who employed a pipe coiled in the form of a helix rotating on a horizontal shaft, steam being passed through the coil, the lower side of which was immersed in the liquor to be evaporated. An improvement on this apparatus was made by Mr. John Aitchison of Glasgow, consisting of a copper cylinder or drum filled with steam, and this apparatus was much used in that neighbourhood, especially for concentrating bark liquor for tanners.

The apparatus that he had himself tried for surface evaporation was formed of an inclined plane or table of cast iron, 22 feet long, made in two thicknesses, steam being admitted between the plates so as to keep the table at a uniform heat; the surface of the table was polished, and one end of it raised a little higher than the other, so that when the liquor to be evaporated was allowed to run on at the upper end, it spread itself over the table and ran down to the lower end, where it was received into the sugar moulds in a state fit for crystallization. One circumstance incidental to this mode of evaporation, which he thought deserved particular attention, was the peculiar power that the air possessed of clarifying sugar; this was a fact of much importance to sugar-growing colonists, and he believed it to be a novelty in sugar refining; he had made the discovery of the circumstance some years ago, but had not previously made known the particulars of it. In the evaporation of sugar on the inclined plane, it was observed that when the thin film of syrup was passing down the table, the boiling action produced by the heated plate caused all the foreign particles of dirt and colouring matter in the liquor to rise to the surface, where the air immediately seized upon them and formed them into a scum which floated along the surface of the liquor and could not sink; when the sugar had crystallized and cooled in the moulds, he all tscum was found on the top in the form of a cake or layer, 1 or 2 inches thick, which was easily taken off, leaving the sugar below in a purified state. He thought some advantage might be gained, where the Bour pan was used, from this action of the air in clarifying the sugar, if proper attention were paid to the subject.

There was however at present unfortunately a serious obstacle to the introduction of any such improved apparatus into the colonies, from the objectionable state of the custom laws. All sugar imported into this country was charged with a high rate of duty, if equal to what was technically called "clayed" sugar, that is, sugar that has undergone a process of claying or refining after being boiled. If therefore the planters in the colonies were to adopt the plan he had described, whereby the sugar was made in the raw state equal to that which had undergone the subsequent process of claying, they would not reap any benefit from the improvement, because the high duty payable on clayed sugar would be charged. This was a subject that affected not only the colonists, but also all the consumers of sugar in this country; for if by the simple process of boiling the cane juice the sugar planter could produce raw sugar of such a quality that it could be used at once without having to pass through the hands of the refiner in this country, the price would be reduced. He hoped the present law would be so amended as to allow the growers of sugar in the colonies to derive the full advantage of any improvements in sugar boiling apparatus that they might adopt; it was certainly a great mistake that raw sugar unrefined but fit for use for general household purposes should be charged with as high a duty as if it had been refined.

Mr. **Harvey** said the remarks that had been made on the very injurious effect of the present custom laws were certainly too true. He had found, as a manufacturer of sugar machinery, that the planters had no inducement to avail themselves of improvements such as had been suggested, as the result would be that they were exposed to a heavier duty, absorbing the advantages they might derive. In the plan of Mr. Aitchison, somewhat similar to the present one, that had been referred to, the drum running the whole length of the evaporating pan had only a small surface, only half that of the discs in the Bour pan of the same length. In the use of the Bour pan, the scumming was generally effected previously in a separate apparatus, consisting of a vessel or trough about 6 feet long 4½ feet wide and 2 feet deep; the trough was heated by 56 steam pipes, of 2 inches diameter, running the whole length and returning to discharge the condensed water into an outer compartment. The syrup was here brought nearly but not quite to the boiling point, the scum being then all thrown to the top and the sediment to the bottom; these were removed, and the process of evaporating and crystallizing was then completed in the disc machine. This kind of clarifier was rather expensive; but very good results had been obtained with the Bour pan combined with the old-fashioned clarifying pan.

Mr. JOHNSTONE observed that the full advantage of the clarifying action of the air would not be gained in the Bour pan when the scumming was effected in the manner just described, the depth of the syrup being such that the air could not act with advantage on every portion of it so as to remove the dirt. In order that the air might act efficiently upon the syrup, it was necessary that it should be spread out in a thin film while hot, as on the inclined table that he had described, so as to expose as large a surface to the air as possible; by this means he had found that sugar of good colour and free from impurities might be made, doing away with the necessity of refining except for making loaf sugar.

The CHAIRMAN proposed a vote of thanks to Mr. Harvey for his paper, which was passed.

The following Paper, by Mr. James P. Joule, of Manchester, was then read :—

ON A SURFACE CONDENSER

The principle of surface condensation as applied to steam engines was as is well known introduced by Watt, who in his first experiments employed pipes immersed in cold water as the means of condensing the steam and producing a vacuum. It was however speedily abandoned by this great man, who substituted for it the injection in a separate vessel, as employed almost universally at the present time. Surface condensation has however since the period of Watt been repeatedly attempted with more or less success by various individuals, among whom may be specially mentioned Cartwright and Hall, the former of whom designed an engine which has been too little studied, though of admirable simplicity and combining all the essential apparatus of a perfect surface condenser; and the latter by his long continued and laborious efforts nobly strove to introduce what he justly considered a great improvement. Without going farther into the claims of the many able men who have laboured unsuccessfully in this direction, it may be remarked generally that the system has not been so much in fault as the imperfect means employed to carry it out.

Having been for a long time impressed with this idea, the author had great satisfaction in embracing the opportunity for experiment which unexpectedly presented itself on the occasion of the erection of a small high pressure engine for the joint investigation of Professor Thomson and himself on the thermal effects of fluids in motion.

The general arrangement of the cylinder and condensing apparatus in this engine is shown in Fig. 1, Plate 78.

The engine has a cylinder A of 6 inches diameter and 6 inches length of stroke, it makes 180 revolutions per minute when going at full speed. Being fitted with the ordinary three-ported valve the steam is cut off only after the piston has accomplished two thirds of its stroke. The force pump B for feeding the boiler is single acting; the ram is $1\frac{1}{2}$ inch diameter with $1\frac{3}{4}$ inch length of stroke, and is worked from an eccentric on a shaft which makes 1 revolution for every $3\frac{1}{2}$ revolutions of the engine. The volume of steam passing through the cylinder compared with the volume of water propelled by the force pump is therefore in the ratio of $6^2 \times 6 \times \frac{2}{3} \times 2 \times 3\frac{1}{2}$ to $(1\frac{1}{2})^2 \times 1\frac{3}{4}$, or as 256 to 1. When the steam is at a pressure of 15 lbs. above the atmosphere, rather less than one third of the capacity of the pump is required in order to keep the boiler full, leaving the remaining two thirds available for the purposes of an air pump.

Although it seemed at first sight impracticable to work the engine with an air pump of so small a size, it was resolved to make trial of it, and accordingly the eduction pipe C was connected with the end of one of the legs D of an iron tube 1½ inch diameter bent into the form of a syphon of 10 feet height, the end of the other leg E being connected by means of a smaller pipe F with the feed pump B. By this means the steam after passing through the cylinder is made to ascend to the height of 10 feet, and afterwards to descend through the iron pipe E 10 feet long and 1½ inch diameter. The descending pipe E is surrounded with a current of water ascending upwards in an outer concentric pipe G of 4 inches diameter, the cold water being supplied from a pump through the pipe H. The condensed water along with the air which enters by leakage is cleared out by the feed or air pump B, the water being forced into the boiler through the feed pipe I, while the air is allowed to escape from an orifice K contrived by loosening a screw in the cover of the pump.

On starting the engine, two stop cocks L and M, one at the lowest part of the syphon leg D near the cylinder, and the other between the valves of the feed pump are opened. The engine then works as a high pressure engine until the boiler and cylinder are cleared of air and the condensing pipes E and F of water. This being effected the stop cocks L and M are closed, and after a few revolutions a vacuum begins to be formed, which increases until the limit arising from leakage of air and the temperature of the interior of the condensing pipe is attained.

The very small size of the air pump would render the above arrangement quite abortive, if any considerable quantity of air leaked into the condenser. Nevertheless it was found that when the engine was working at one horse power including friction, that is raising 33,000 lbs. one foot high per minute, a vacuum of 23 inches could be maintained, the barometer at the same time standing at 29 inches. This single experiment demonstrates in the author's opinion the practicability of the system of surface condensation as adopted in the present instance, and shows also that it must speedily supersede the method at present used. A vacuum of 23 inches may indeed be considered an extraordinary result, when the smallness of the air pump is considered, and when the leakage of air arising from a variety of junctions and stop cocks, and particularly from the stuffing box of the piston rod, is taken into account. Were these disadvantages obviated, as they might easily be, there is little doubt that the vacuum would equal that of most condensing engines. It is therefore concluded that one iron pipe 10 feet long and 1½ inch diameter is sufficient to effect adequate condensation for a one horse power engine, and that of course 100 such pipes would answer for a 100 horse power engine.

It will hardly be necessary to urge on practical engineers the immense importance of surface condensation if once practically carried out. The disadvantages of the present system are well known: the boiler is turned into an evaporating basin, on the sides of which a hard deposit of carbonate of lime is formed; or if this is avoided, it gradually becomes filled with the saturated solution of a salt. In the one case, a greatly increased consumption of fuel takes place, owing to the bad conducting power of the deposit; in the other, loss of heat and various inconveniences are the inevitable consequences of the necessity of blowing off the saturated and foul water. Besides this there is always a difficulty in keeping the water in the boiler at a proper level, entailing the necessity of a variety of contrivances for regulating the supply. When to the above objections is added the power lost in the friction of a large air pump, and the work it has to do in pumping out the injection water, it will be allowed that a surface condenser which obviates these disadvantages will compete successfully with the common system, and would do so even though the vacuum were inferior to that of the ordinary condenser by half a dozen inches.

But the superiority of surface condensation does not rest with the above considerations alone. If the vacuum is imperfect through want of sufficient cooling surface, that deficiency is made up to a considerable extent by the higher temperature at which the water is returned to the boiler. In fact, as has been correctly observed by a previous writer, there is a limit beyond which the condensation cannot be advantageously pushed. This limit will be lower for surface than for injection condensation, as in the latter case the additional injection water adds to the work of the air pump. Another and highly important consideration is that by the proposed plan the refrigerating power of the cold water employed for condensation is more perfectly used up. In the ordinary condenser the perfection of the vacuum is that due to the lowness of the temperature of the hot well, but in the system here advocated it is possible, by causing the current of cold water to meet that of the steam to use the former as a refrigerating agent until it arrives at a much higher temperature than that due to the pressure of the attenuated vapour in the condenser.

Although the present experiments have not been sufficiently extended to determine with great precision the form and dimensions of a surface condenser for an engine of given power, the author thinks he can safely recommend the refrigerating surface above indicated per each horse power. A sufficiently capacious pipe should convey the steam after passing through the cylinder to a chest placed 12 feet above the level of the base of the air pump. Another similar chest with a pipe proceeding from it to the air pump should be placed immediately under the above, and at about the level of the foot valve. Vertical pipes about 10 feet long and $1\frac{1}{2}$ or 2 inches diameter, in number equal to the horse power at which the engine is estimated, and placed as near one another as convenient, should form a communication between the upper and lower chests. As it is of great importance that these pipes should be easily removed and put on again air tight, short pipes might be permanently fixed to the chests for this purpose, to which the vertical condensing pipes might be conveniently attached by means of pieces of vulcanized india rubber tubing secured by metal clamps. The condensing pipes thus arranged should then be plunged into a cistern in which a current of water flows upwards. It is desirable not to allow too much water space between and around the pipes, in order that by a rapid motion of the refrigerating water, it may be prevented from adhering to the surface of the pipes. The air pump if worked at the velocity of one stroke per second ought to have a capacity of about 10 cubic inches for each horse power. The water passes immediately from the pump to the boiler, but the air escapes through a small orifice in the cover of the pump. To prevent the escape of water by this orifice a contrivance like that in Cartwright's engine may be employed, consisting of a valve opening inwards, attached to a lever carrying a ball floating on the surface of the water, so as to close the valve when the water rises.

An improved construction of surface condenser, similar in principle to the above, has been proposed by Professor Thomson, and is shown in Fig. 2. It consists of an enlargement of the cold water pipe N, in the form of a large pipe or chamber O, connected to the pipe N by the joints P and R at the top and bottom. The chamber O is closed at the ends by two plates S and T, perforated with a number of holes, as shown in

Fig. 3, to receive the condensing tubes U, which are proposed to be fine copper tubes as small as $\frac{1}{10}$th inch inside diameter, fitting well but not tight in the holes in the tube plates. The joints are made water tight by a disc of india rubber, perforated in the same manner as the tube plates, and placed below the lower plate S and above the upper plate T. A second plate may be added outside each india rubber disc, and screwed up tight to the tube plate by means of bolts, so as to press the india rubber well round the tubes and make a water tight joint. The vacuum pressure however will probably be sufficient to keep the india rubber tight round the tubes, and the second plates and tightening screws will then be dispensed with. The exhaust steam enters the condenser at the top by the pipe V, and the cold water flows upwards through the pipe N and tubes U. The condensed water is drawn off from the bottom by the pipe X leading to the air pump. By this plan there are no joints for leakage of external air into the vacuum except the ordinary joints for the connexions of the exhaust pipe to the valve chest and condenser. The joints in the tube plates have water on the outside and the vacuum of the condenser on the inside, so that any leakage through them would simply give a little injection water, to which no supporter of the present system can object; the amount of leakage may however be made so slight as to be practically imperceptible. It should be observed that there is an important difference between the condenser now proposed and the previous tubular condensers, in which the steam passes through a series of tubes surrounded by water, so that the deposit from the water takes place on the outside of the tubes and cannot be cleared away; whereas in the proposed condenser the conditions are reversed, and the deposit takes place inside the tubes and can be easily removed by passing a rod down the tubes when requisite, the cover of the condenser being readily taken off for this purpose.

The farther improvement of separating the work of clearing the condenser of air and drawing out the condensed water has been proposed by Professor Thomson as follows:—"It appears to be an ill-arranged plan to pump out air and water in not very unequal volumes with a large proportion of watery vapour besides, which is the work allotted to the *air* pump, so called, of an ordinary condensing engine; and true economy would probably be found in a division of labour. Whether surface condensation or injection be used, the air and water to be drawn out might readily be separated by having a *water* pump employed to draw from the bottom of the condenser, of very little larger capacity than would be sufficient for all the water to be pumped out, and by having also a branch pipe from the condenser near the top leading upwards to an *air* pump, this pipe being specially cooled by a separate refrigerating stream of water to itself, so that the temperature in it might be lower than it is practicable to attain in the condenser, as low in fact within a degree or two as that of the cold water supply. There would thus be a much more perfect condensation in the pipe than in the condenser, and the condensed water would run down it, leaving above at the entrance to the air pump chiefly air at the same pressure as the vacuum in the condenser. In an ordinary steam engine with injection there would be a risk of the water rising in the condenser and choking the air pump; but this might be avoided by supplying the condenser with a glass gauge, so that if the water rose too high the injection stream might be diminished. Where surface condensation is used it would still be desirable to be able to regulate the height of the water in the condenser; and for this purpose some plan of adjusting the feed pump to make it draw more or less as required would be advisable, so that the pump might draw off just enough to prevent a rise of water in the condenser."

The importance of working the steam expansively is evident, whichever system of condensation is employed. In fact when steam is properly used in the cylinder it passes at a low temperature and pressure into the condenser, and then a good vacuum is easily attained with a comparatively small quantity of condensing water. It may here be remarked that it would be very desirable to abandon the practice of using the same port for both the induction and eduction of the steam to and from the cylinder, since by this method the temperature of the exhaust steam is raised by coming in contact with metal which was the instant before heated by the induction steam, and the induction steam is cooled by contact with metal which has just before been exposed to the exhaust steam. No doubt a loss of elegance and compactness would result from employing separate ports, but this would be far overbalanced by the real advantages gained.

It has been proposed to employ air as the refrigerating agent for surface condensation. Could this be successfully realized, a most important practical result would be attained, for it would make the steam engine available in localities where a good supply of water cannot be met with. Experiments are about to be made by Professor Thomson and the author on the power of air as well as inelastic fluids as refrigerators, and it seems almost certain that the quantity of air which has the same capacity for heat as a certain quantity of water would effectually replace the latter as a refrigerator in a surface condenser. The volume of air would necessarily be great, but the labour of pumping would not, it is apprehended, present any serious disadvantage.

Professor W. Thomson regretted that Mr. Joule was unfortunately prevented from being present; but having been Mr. Joule's colleague in the experiments and trial, he would be happy to answer any enquiries on the subject.

The principle of surface condensation was not novel, but it was here introduced under a novel application. When the surface condenser was first attempted by Mr. Joule, it did not act well for some time; afterwards however it worked better, and on examining into the cause of the change, a bolt was found to be loose in the pump; on partially unscrewing the bolt, the good result stated in the paper was obtained, the narrow orifice thus formed allowing a little escape of air at the end of the stroke of the pump; and this circumstance led to the arrangement now described. It was easy to ensure very little leakage of air in those parts of an engine where the pressure of steam was below the atmosphere, if the joints were good; the model that had been tried had only iron tubes with india rubber joints for the condenser, but on a larger scale the joints could be made almost perfectly tight, and the stuffing box of the piston rod was the only place where any difficulty need be apprehended. It was essential to secure a very complete exclusion of air, as a small proportion of air leaking in would injure the vacuum in the condenser. The model engine had been found to run with considerable power for a quarter of an hour after the pressure of steam in the boiler had fallen below the atmosphere; but on opening a stop cock in the boiler for only half a second, enough air was admitted to stop the engine. There was no doubt that the injection water in ordinary condensing engines introduced most of the air that had to be pumped out, as bubbles and dissolved in the water;

and the absence of injection water in the model engine accounted for the excessively small size of air pump required, very little exceeding the size required for the feed of water to the boiler; in the experiments the original feed pump had been found quite sufficient for the air pump.

In Mr. Joule's present trial, the full effect of a rapid stream of water, in producing condensation, had certainly not been obtained; and from the experiments he thought that much less surface of the condenser would be required, if a greater velocity of the stream of water were employed. The imperfect conducting power of the metal appeared to be a less obstruction than the clogging of the water, caused by the heated particles not being quickly enough carried away and replaced by cooler ones; he was accordingly led to the conclusion that a still smaller surface would ultimately be found sufficient.

Mr. FAIRBAIRN had had an opportunity of witnessing the experiments made by Mr. Joule and Professor Thomson, and thought them well worthy of attention. In the experimental boiler the supply of steam had been scarcely sufficient, the furnace being somewhat imperfect, and the steam pressure was soon up and down. There could be no doubt that a surface condenser would be of great advantage, particularly in marine engines, if the practical difficulties attending it could be overcome. Hall's surface condenser had been perseveringly tried, but had been abandoned, because found more expensive in working the engine than the injection condenser, owing mainly to the complexity of construction and the difficulty of keeping it in good order.

Mr. HARVEY thought the surface condenser proposed was a very ingenious plan, and deserved a complete trial. In the construction of Hall's condenser there was great difficulty in keeping the joints tight at the ends of the pipes; the pipes were fixed by ferrules and were apt to leak at the ends, letting in air and seriously damaging the vacuum. He had seen recently at Mr. Weems', near Glasgow, a construction for a different purpose, which might be suitable for getting over this difficulty; it consisted of 400 iron tubes of $1\frac{3}{4}$ inch diameter fixed together as in the tubular condenser, and by tinning the ends and dipping the whole set a little depth into a bath of melted tin, with iron plugs coated on the ends to prevent the tin from getting into the tubes, a lump or layer of tin was formed at each end of the tubes, which acted as a tube plate of simple and air tight construction, though of course not admitting of the removal of single tubes.

Mr. James R. Napier believed that the objection experienced in Hall's condenser arose not so much from air leaking in through defective joints, as from the accumulation of grease and tallow from the engine inside the small pipes of the condenser, which was found to choke them up. He stated that Mr. David Napier used a surface condenser many years ago in the steamer "Postboy," and one was lately working in his boat on the Thames. He believed the greatest difficulty when the condensers were tight was to keep the boilers clean, as the grease and dirt from the engine got deposited there and formed a sort of tarry matter which it was difficult to get rid of.

Mr. Johnstone had been some years ago on a steamer on the Thames belonging to Mr. David Napier, in which surface condensation was effected by means of a double bottom to the vessel; it worked very well, but the boiler primed so much from its peculiar construction that the surface condenser had scarcely a fair trial.

Mr. Tosh had had a 10 horse power engine working for two years with a surface condenser, consisting of a cast iron cylinder 10 feet long and 12 inches diameter, with 30 brass tubes of the same length and 1¾ inch diameter passing through it; it had worked satisfactorily and had not been found to get choked up, and there had been no difficulty in keeping the ends of the tubes tight; it had the advantage of keeping the boiler clean, although the water was very bad. The quantity of water required to condense the steam had not been ascertained, but all the water for the supply of the locomotives at the station where the engine was fixed was passed through the condenser.

Mr. Fairbairn thought that in the condenser proposed by Mr. Joule a large pump, taking considerable power to work it, would be required to propel the water through between the pipes, in order to maintain a sufficient circulation of water to carry off the heat and condense the steam. If the spaces between the tubes were made narrow, and the water passed at a great velocity between them, impinging with more or less force on the tubes, considerable power would be required to supply the water, and it would become a question whether there would be any saving of power compared with that required to work the ordinary air pump, taking into consideration the greater imperfection of vacuum in the surface condenser.

Professor Thomson considered the power required for propelling the water between the tubes would be much less than for discharging the water from the air pump in the ordinary condenser. The power appeared to be very little in Mr. Joule's experiment, and the extra power required to give a rapid motion of the water between the tubes could be but small in amount. There was a remarkable difference in the cooling effect of a current, whether of water or air, according to the velocity at which it moved; when the water was slowly propelled it became clogged as it were, a little layer of heated water being formed round the tubes, which parted with its heat very slowly to the surrounding water; but with the water in rapid motion, the succession of cold particles brought into contact with the tubes rapidly conveyed the heat away.

Mr. Neilson thought the small experiments that had been made, although giving such good results, could scarcely be relied upon till confirmed by trials on a large scale; he anticipated that no mode of condensation would prove so effective as a jet of water, which had formed the great improvement in Newcomen's engine over the previous plan of surface condensation. Many subsequent attempts had been made to employ surface condensers, and no one had tried at it more than Mr. David Napier; but he doubted whether a sufficient surface of water or air could be obtained in practice, to condense efficiently. In Mr. Joule's proposed condenser he thought the pump required to give the necessary velocity to the water would be likely to absorb the power saved from the ordinary air pump.

Professor Thomson thought that the general partiality for condensation by injection arose mainly from the imperfect manner in which surface condensation had been hitherto attempted, owing to the want of a continuous rapid current flowing past the surface of the tubes. He fully expected that a sufficient current could be maintained with a comparatively unimportant expenditure of power; and it must be remembered that the advantage of a pure supply of water for the boilers was an important object to be attained, but not practicable where condensation was effected by injection.

The Chairman proposed a vote of thanks to Mr. Joule for his paper, and also to Professor Thomson, which was passed; and expressed the hope that they would communicate at a future meeting the farther results of their investigations in this important subject.

The Meeting was then adjourned to the following day.

In the evening the Members were invited by the Local Committee and their friends to a Conversazione in the Corporation Halls, Sauchiehall Street, where an extensive collection of models, specimens, and engineering drawings and photographs, was exhibited.

The Adjourned Meeting of the Members was held in the Scottish Exhibition Rooms, Bath Street, Glasgow, on Thursday, September 18th, 1856; Joseph Whitworth, Esq., President, in the Chair.

The following Paper, by Mr. John Reid, Jun., of Glasgow, was read:—

DESCRIPTION OF BOUCHERIE'S PROCESS FOR THE PRESERVATION OF TIMBER.

The process which it is the object of the present paper to describe forms an important improvement in the mode of preparing timber so as to preserve it from decay. It is the invention of the eminent French chemist, Dr. Boucherie, who has been engaged nearly twenty years in bringing it to perfection, and is one of the most effectual processes for rendering durable wood that is liable to decay.

The tubular structure of trees has long been known; but the fact that there is no lateral or transverse communication between the tubes has been ascertained only recently. This fact has been experimentally demonstrated by injecting a colouring liquid at one end of a log, a particular portion only of the end being exposed to the liquid; it was then found that in any transverse section of the log the wood was always stained in exactly the same part. In this manner the letters of a word have been driven from one end to the other of a piece of timber. This fact forms the basis of the present process, the principle of which consists in forcing into the timber a liquid of a preservative nature, causing it to infiltrate into the fibres of the tree as it would into a series of small parallel tubes.

In the first attempts, the vital energy of the trees was employed to draw in the liquid by means of the circulation of the sap, and the liquid was thus distributed into every part of the wood, and even into the finest tissues of the leaves. As the circulation of the sap however continues for several days, even after the tree has been felled and stripped of its foliage, another process was subsequently adopted, by which the liquid is forced through the timber by an end pressure in a simple and economical manner. The sap is thereby expelled and oozes out from the end of the timber, which is thus freed from the most active source of decomposition and at the same time injected with a liquid incapable of decomposition under all ordinary circumstances.

The following is the method which up to the present time has been found to be most economical and practicable for carrying out the process on a large scale in the preparation of railway sleepers.

After the tree has been felled, a saw cut, Figs. 1 and 2, Plate 76, is made across the centre through about nine tenths of the section of the tree. The tree is then slightly raised at the centre by a lever or wedge, so as to open the saw cut a little, as in Fig. 1; a piece of string or cord is placed all round the edge of the saw cut, and on lowering the tree again the cut closes upon the string, as in Fig. 2, which thus forms a water tight joint in a simple and effectual manner. An auger hole is then bored obliquely into the saw cut from the outside, into which is driven a hollow wooden plug, shown enlarged in Fig. 5. A flexible tube is fitted on the plug, the end of which is made slightly conical so that the tube may be pushed tight upon it. The tube communicates with a raised cistern, placed at a height of from 30 to 40 feet above the timbers that are to be prepared, and containing the solution of sulphate of copper used for the purpose. When the preparations have been completed in this manner, the liquid flows through the tube into the saw cut in the tree, and forces itself along the log in both directions, driving the sap out at each end. As soon as the liquid has reached the ends of the log, the process is finished and the log is ready for use.

If the timber is required of the entire original length, the cross saw cut at the centre cannot be made, and in this case the plan shown in Figs. 3 and 4 is substituted. A cap consisting of a piece of board, ¾ inch or 1 inch thick, is fixed on the end of the log by screws through the board into the tree or by dogs screwed at the end and fitted with a nut; the joint is made by a piece of string or cord as before, and the cap is screwed up tight on the cord. As the direction of the grain in the board forming the cap is transverse to that of the tree, the liquid cannot pass through the cap, and the injection proceeds from one end of the log to the other.

In order to ascertain when the process has been continued for a sufficient length of time, so that the sap has been all expelled and replaced by the solution of sulphate of copper, a piece of prussiate of potash is rubbed on the end of the timber while in the damp state, and if the solution has reached the end of the log a deep reddish brown stain is produced, showing that the timber is thoroughly impregnated with sulphate of copper.

The sap expelled from the timber in the process of impregnation contains at most only 1-1000th part of organic matter in solution, and accordingly no inconvenience is experienced in employing it as a solvent for the sulphate of copper. It is indeed preferable to many kinds of spring water, particularly those containing lime, which decompose a considerable proportion of sulphate of copper. Troughs are therefore laid under the ends of the logs, as in Figs. 1 and 2, to catch the sap and the waste solution, which are conducted to a reservoir to be pumped up to the cistern and mixed with sulphate of copper to the proper strength.

The solution that has been found most effectual for preserving the timber is composed of 1 part by weight of sulphate of copper and 100 parts by weight of water. The strength of the mixture is ascertained by a hydrometer having a properly graduated scale. The specific gravity of water at 60° Fahr. being 1000, if 1 per cent. of sulphate of copper is added, the specific gravity of the mixture will be 1006 nearly.

The sooner the trees are prepared after being felled the better, and it is therefore advisable to prepare them as near as possible to the place where they are felled. Trees felled at any time between November and May may be prepared in May; but those cut down in May or at any time from May to the end of November should be prepared within three weeks from the time of being felled.

In the course of the operations carried out in the practical application of this process, the following facts have been ascertained:—

All kinds of wood do not absorb equally, and the absorption of the liquid is more rapid in the sappy parts than in those nearer the heart of the tree.

The quantity of the solution forced into the timber is equal in cubic measure to at least one half of the cubic dimensions of the timber. When a solution containing about 2¼ lbs. of sulphate of copper in every 22 gallons has been forced through a log, it appears, after allowing for the sulphate carried off by the sap, that every 35 cubic feet of wood have retained from 11 lbs. to 13 lbs. of sulphate of copper.

For a log about 9 feet long the process of impregnation occupies two days, when the timber is newly felled and the solution is supplied by a head of about 3½ feet. If the wood has been felled three months, three days are required; and if four months, four days are necessary to complete the impregnation.

The greater the elevation of the cistern from which the liquid is supplied, the more rapid and complete is the process of saturation. The influence of pressure however is perceptible only in wood that readily admits of penetration, such as beech, hornbeam, birch, Scotch fir, &c. The attempts made to force the liquid by means of pressure into wood which under ordinary conditions is impenetrable have proved altogether ineffectual. Of different kinds of trees, those which possess most moisture are most easily penetrated by the solution, and of the same kind, those which have grown in the dampest soils. Hence the least valuable and cheapest kinds of timber are precisely those which give the best results when impregnated with the sulphate of copper.

The process may be carried on all the year round, excepting at temperatures so low as to freeze either the solution to be injected or the sap which oozes out of the timber.

The present process may be employed with advantage for preparing timber in all cases where it is liable to decay. Railway sleepers and telegraph posts, ship planking, timbering for mines, wood fencing, gates, farm buildings, and other structures of wood, will last many additional years if prepared in this manner. The process may be successfully applied to cheap wood of quick growth, such as Scotch fir, beech, elm, and other timber grown in this country; it is not necessary that the wood should be dried or seasoned before being prepared, but on the contrary the operation is best effected immediately after the tree is cut down.

Mr. Reid exhibited samples of the solution of sulphate of copper used in the process of preparing the timber, containing 1 per cent. of the salt; also a specimen of the cross section of a sleeper, stained in the form of the letters of a name, the letters being equally visible in any cross section of the sleeper. He showed also a sample of the sap recently expelled from a piece of timber by the process; and exhibited the action of the test for ascertaining the extent of saturation, the timber being stained deep brown on rubbing with prussiate of potash, when properly saturated with the solution of sulphate of copper. He said the process would also be shown in operation after the meeting on full-sized timber cut down a few days previously.

Mr. Scott Russell enquired what was the mechanical mode of applying the cap and tube for injecting at the end of the timber, and whether it could be readily applied to any timber.

Mr. Reid replied that the cap put on the end of the timber was made of any piece of hard wood, fitted water tight on to the timber with an india rubber packing ring; the solution was then injected into the cavity of the cap by a flexible tube from the main pipe leading from an elevated cistern. The ordinary and cheaper plan however, and that generally adopted for railway sleepers, was to inject in the middle of the length of the timber, where it was intended to be cut up afterwards; a cross saw cut was made in the middle nearly through the timber, and a piece of cord placed in it round the edge to form a water tight joint; the solution was then injected into the cut through an auger hole.

The Chairman asked what length of time the process had been thoroughly tested, and what was the severest test the prepared timber had been subjected to; also whether it had ever been tried by long exposure in cellars where the dry rot prevailed. He remembered the late Mr. Cubitt had a cellar where he tried samples of all kinds of timber, but he could never get any to stand the dry rot, all sorts of timber becoming decayed before any great length of time.

Mr. Reid replied that the longest trial that had been made was of some railway sleepers in France, a number of which had now been laid on the Northern Railway for a period of 8 years, and continued quite sound and satisfactory. He was not aware whether the effect of the preparation had been tried in resisting dry rot in the manner alluded to.

Mr. Fothergill asked whether any attempt had been made to saturate the timber by an exhausting vessel, to remove the sap and open the pores of the timber, and by then introducing the solution by opening a tap whilst the exhaustion was continued.

Mr. Reid said that mode of injection had not been tried, the object having been to save machinery and obtain the result with the simplest description of apparatus, so that it could be readily and cheaply erected at any place where the timber was felled.

Mr. Scott enquired whether large squared timber, such as seasoned Memel or American pine, could be saturated by the process, or whether it should be done in the log before being cut up.

Mr. Reid replied that large timber partially squared had been thus prepared in France for the navy, but the process did not answer so well for squared Memel and other imported timber, since in order to do it advantageously it ought to be performed as soon as possible after the tree was felled. The best plan was to perform the process on the tree in the forest, for after it had been squared the fibres were so intersected by the cut faces that the solution was not carried completely through all parts of the timber.

Mr. Scott asked whether creosote could be injected in the same way, and what was the relative expense of the two processes for preserving timber.

Mr. Reid said that the creosote of the quality in general use would not flow in sufficiently by a head pressure like the solution of sulphate of copper, and machinery was required to do creosoting in the most efficient and economical manner; but as the cost of labour was less, the total expense of the two processes came to about the same. The ordinary 9 feet railway sleepers cost about 1*s.* each prepared with the sulphate of copper.

The Chairman proposed a vote of thanks to Mr. Reid for his paper and the specimens exhibited, which was passed.

The following Paper, by Mr. James Robertson, of Ardrossan, was was then read:—

ON GROOVED-SURFACE FRICTIONAL GEARING.

The object of this paper is to describe a system of frictional gearing recently introduced by the writer, intended chiefly for high speeds; and to give such information regarding its action and driving capabilities as the several applications of it in use will afford.

The grooved-surface frictional gearing consists of wheels or pulleys geared together by frictional contact, communicating motion independently of teeth or cogs; the driving surfaces are grooved or serrated annularly, the ridges of one surface entering the grooves or furrows of the other. The extent of contact is thus increased in the direction of the breadth of the rim, and a lateral wedging action is obtained, which augments the effect of the pressure holding the wheels in gear, the necessary amount of which is felt to be so injurious to the bearings of the shafts when the power is communicated by plain driving surfaces.

The grooved-surface gearing is shown in Figs. 1 to 15, Plates 79 and 80, under a variety of modifications. The grooves are made angular or V shaped, as shown full size in Fig. 16, and are found to suit best when formed at an angle of about 50°. The pitch or distance between the grooves is varied according to the velocities of the wheels and the power to be transmitted; the smallest pitch employed is $\frac{1}{8}$ inch, and that required for the very heaviest operations about $\frac{3}{4}$ inch. The ordinary pitch is about $\frac{3}{8}$ inch, as shown full size in Fig. 16. The wheels are turned up truly, and the grooves equally pitched and made exactly alike on each face with a turning tool similarly formed to a common screw-cutting tool, so that on applying the surfaces to each other a well fitted contact throughout the faces is obtained. In order to increase and sustain the wedging action, the points of the ridges are left blunt, as in Fig. 16, to prevent them from reaching to the bottom of the grooves.

Cast iron has as yet been the only material used in the construction of the grooved wheels, and its action has been found so satisfactory that there is no necessity for trying any other. The surfaces after working a short time together assume a smooth polished appearance, taking a greater hold in proportion to the smoothness they acquire; and when a sufficient breadth for the speed and power to be transmitted gets into contact there is afterwards no perceptible tendency to wear.

The friction caused by the contact of the grooved surfaces appears to be governed by the same general laws as in the case of plain surfaces:—it bears the same proportion to the force by which the surfaces are pressed together, whatever be the amount of that force; it is independent of the extent of surface in contact; and, the amount of friction caused by the action of the surfaces in motion is independent of the speed of the motion. The only points that have to be attended to therefore, so far as the power or driving contact is concerned, are the angle of the grooves, and the pressure holding them in contact, the extent of surface in contact being determined so as to prevent abrasion and withstand the wearing action. With respect to the law relating to the constancy of the amount of friction irrespective of the velocity of motion, so far as is yet ascertained there is no evidence that it does not also apply equally with the two other laws: but the friction of two wheels rolling on each other, so long as there is no slipping action, is more properly the friction of quiescence than that of motion; for though in motion, the points in contact in the line of centres may be regarded as being momentarily at rest. In the experiments instituted by the French Government, conducted by M. Morin, the friction of plain flat cast iron surfaces without any lubrication is given at nearly one sixth of the pressure holding them in contact; and it is generally understood that plain-surface pulleys or wheels give nearly the same results. In the case of wrought iron the friction is somewhat greater, as shown by the adhesion of the wheels of locomotive engines on the rails. The general laws of friction do not however apply so closely to the action of wheels of all diameters as to flat surfaces; wheels of large diameter or more nearly approaching to flat surfaces show a decided superiority of action. With grooved surfaces also the superiority of large wheels to those of small diameter is very apparent.

In Plates 79 and 80 the grooved-surface gearing is shown as applied to various forms of spur and bevil wheels.

Figs. 1 and 2 represent a pair of spur wheels, A and B, geared by the frictional contact of the grooves formed on their surfaces.

Figs. 3 to 5 show a plan for obtaining a high speed from the driving belt, without the usual arrangement of counter shafts and belt pulleys between the main driving shaft and the machine to be driven, and without the disadvantage of passing the belt over a small pulley. A small grooved pulley C is keyed on the shaft to which the high velocity is to be communicated, and upon it is placed a loose inflexible ring *D*, of two or three times the diameter of the pulley, grooved internally to fit it, and turned up smoothly on the outside to receive the driving belt E. The belt gives motion to the speed ring D, the inner grooved surface of which communicates a higher speed to the pulley C. The speed ring is held in its position and in effective driving contact by no other guide or pressure than the position and tension of the belt. Figs. 6 to 8 show a double speed ring for obtaining increased lateral steadiness at high speeds, if required. By these arrangements a belt may be passed over a speed ring of 16 inches diameter, and yet communicate the same speed to the shaft as if it were passed over a pulley of only 4 inches diameter.

Figs. 9 and 10 show a pair of bevil wheels, F and G, geared by means of grooved surfaces.

Figs. 11 to 13 show a clutch arranged for engaging and disengaging by means of grooved surfaces. The two discs H and I are formed with corresponding circular grooves on their faces; the disc I is driven by a belt and pulley K, and revolves loose on the shaft between collars; the disc H slides longitudinally on the shaft, to which it is connected by a couple of keys. The clutch is engaged and disengaged by means of the handle L, a very small motion of which is sufficient. By adding a second pair of grooved discs with a second belt and pulley on the other side of the handle L, a reversing clutch of simple construction is obtained, the second pulley being of course driven in the opposite direction to the pulley K.

Figs. 14 and 15 represent an arrangement for reversing in a simple manner. The main driving shaft carries a disc M having two projecting rims N and O formed upon it; the outer rim N is grooved on the inside and the inner rim O on the outside with corresponding grooves. The shaft that is to be driven carries a small grooved pulley P, the diameter of which is slightly less than the distance between the two grooved rims. The motion of the pulley P will then be reversed by moving it slightly nearer to or farther from the main driving shaft, so as to throw it into gear with the inner or outer rim respectively. This plan will be found of great advantage in screw steamers, allowing the screw propeller to be reversed, while the engines are working continuously in the same direction; the propeller will of course be driven at a reduced speed when reversed, but this is of little importance in running backwards.

For comparing the pressure required to hold the grooved surfaces in gear and the power transmitted, various opportunities have occurred in the actual use of the frictional gearing, and arrangements have been made for purposes of experiment. One method of comparing its driving capabilities with those of belts is directly obtained by the simple speed ring movement already described for raising high speeds. One of these speed rings, of the form shown in Figs. 3 to 5, has been working satisfactorily on a large foundry fan for some time; and from the circumstance that the fan was previously driven by a belt of the same size over a plain pulley of the same diameter as the small grooved pulley now used, this case affords a certain practical means of comparing the efficiency of these two methods of communicating motion. Before the application of the ring, the belt was passed over a pulley 6 feet diameter keyed on the driving shaft, and over a pulley 7½ inches diameter on the fan spindle; but the continual bending of a large heavy belt over a pulley of so small diameter made it difficult to keep up the proper driving tension, and the belt was speedily cut up. The ring now interposed between the belt and pulley is 13½ inches diameter, and saves the belt from injury by the greater diameter over which it bends. The ring works steadily, and drives the fan at the same speed as when the belt was passed directly over the small pulley, thereby showing that the grooved metal surface does not strain the bearings more than the ordinary arrangement of driving by belts.

Another method has also been employed for comparing the driving capabilities of the grooved-surface gearing with those of belts, by means of a testing apparatus, having the same pressure on the bearings of the axis as is produced by belts. The testing apparatus is made by gearing together two spur grooved wheels, each 21 inches diameter and 3½ inches broad across the face, the grooves being cut at $\frac{3}{8}$ inch pitch and at the angle of 50°. Motion was communicated to the driving wheel by a 7 inch belt over a pulley 30 inches diameter, so disposed that there was no pressure to hold the two wheels in gear but the pull or strain of the belt. A plain friction strap wheel was keyed on the spindle of the driven wheel, with a strap and break handle attached, so that it could either be retarded or stopped. On applying the break, it either caused the belt to slip or stopped the driving engine, without the grooved wheels showing any tendency to slip.

The testing apparatus is also arranged for the more interesting experiment of indicating by graduated levers the amount of bite or driving hold under various pressures. The various pressures that have been tried show a uniform driving power of one and a half times the pressure applied to hold the grooved surfaces in contact; or, the pressure on the axis is only about one ninth of that which would be required with plain cast iron surfaces of the same breadth to produce the same effect. In other words, the wheels require a force of 3 lbs. acting at their circumference to make them slip, for every 2 lbs. of pressure applied on the axis. It is evident that this moderate pressure on the axis would not be felt to be any serious inconvenience in many positions in mill and other gearing, or in the general construction of machines. So far as the writer has been able to ascertain there are no recorded experiments that have been instituted to determine with how much force toothed spur wheels tend to press each other outwards in the direction of their line of centres when the strain is upon them; but judging from the strength of the bolts usually employed to hold them in place, this force would be considerable; and should it be the case that they press outwards with a force equal to the pressure necessary to hold the grooved pulleys in contact when transmitting the same amount of power, then the friction on the bearings in both modes of communicating power would be the same. To submit toothed wheels to a satisfactory test for this purpose would however be a work of some difficulty and expense.

There is a difference between the friction produced on the axes in toothed wheels and in friction wheels, which might possibly escape attention. The pressure on the axes of the friction wheels in the direction of their line of centres is the same, if the motion is uniform, whether the power they transmit be much or little: whereas toothed wheels, when there is little strain being passed through them, or when they can be moved by hand, appear freer in their action than friction wheels; but when a great strain is being passed through them, the friction caused by the slipping action of the teeth and by the pressure on the bearings is considerable.

There is a slight slip or irregularity in the rolling action in the grooved wheels, which does not occur in the action of plain surfaces, arising from the difference of the diameters of the points of the ridges and the bottoms of the grooves; but this slipping is little felt in practice, and when measured is inconsiderable in amount. In a pair of grooved wheels 8 feet diameter and 1 foot broad with 24 grooves working together, there is a slip of only 10 square inches in an entire revolution; whereas in toothed wheels of the same breadth and diameter with cogs at 3 inches pitch of the ordinary proportions, there is a surface to slip over at each cog of about 24 square inches or nearly the entire area of one side of the cog, making a total slip of about 16 square feet every revolution.

Returning to the question of the pressure required by the grooved wheels to hold them in gear, it may be well to instance a case in which the amount of pressure required for accomplishing a given amount of work could be calculated. Take for example screw propeller gearing, with a wheel of 8 feet diameter and a pinion of 2 feet 8 inches diameter; the engine shaft working at 40 revolutions per minute would give 120 revolutions per minute to the propeller, and 1000 circumferential feet of motion per minute to the rim of the wheel. Adopting the standard calculation of the effect of one horse power as equivalent to raising 33,000 lbs. one foot high per minute, the dynamical effect of one horse power is represented by a weight of 33 lbs. acting at the rim of the wheel; therefore as shown by the testing machine 22 lbs. of pressure on the engine and propeller shafts for each horse power of the engine, or for every 33 lbs. at the rim of the wheel, is all that is required to keep the propeller pinion in contact. This would make a total pressure of 2200 lbs. or about 1 ton for an engine of 100 horse power. It need hardly be remarked that even if the pressure required were found in practice to be double that amount, it would yet be inconsiderable; and with an internal wheel, such as that shown in Figs. 14 and 15, the weight of the pinion if made of the ordinary proportions would be quite sufficient to give the required driving adhesion. Wheels of this description applied for this purpose would amount to less in original cost than those now in use; and so far as their durability is concerned, if properly proportioned they seem scarcely liable to wearing action at all.

Lengthened experience is necessary to ascertain the smallest breadth of face that will be sufficient for transmitting a given amount of power without abrasion or wearing action; and it is therefore preferred at present to make the grooved wheels broader in every position than seems to be absolutely necessary. The general proportions of toothed wheels, as regards both breadth of face and other dimensions, are sufficiently strong for transmitting the same power by grooved surfaces; but the writer is of opinion that less breadth of face and lighter proportions of arms and rims can be used with safety. If the grooved wheels are employed in every position in a factory where wheel gearing is required, no shocks or jolting action can take place; and therefore all the wheels themselves and also the shafting and supports may be made much lighter than can be used with ordinary gearing.

One of the principal advantages of these grooved wheels is their smoothness of action; in positions and at speeds when ordinary toothed gearing produces a disagreeable jarring noise, their action is scarcely audible.

Various mechanical arrangements may be adopted for holding the surfaces in contact by springs or elastic substances placed behind the bearings to press in the line of their centres. Where the relative positions of the spindles or shafts will admit of one wheel resting with its own weight on that with which it is geared, there will be an advantage, as the upper wheel can be made of sufficient weight to give the necessary adhesion, thereby relieving the bearings of all superfluous strain. Where bevil wheels are employed, no arrangements of the bearings to obtain the driving adhesion are necessary; but the required pressure may be obtained by making the arms of one or both of the wheels corrugated, as in Fig. 10, and the wheels when being keyed on the spindles can be adjusted to any required pressure, in consequence of the slight elasticity of the arms.

One application of the grooved wheels has been made in which malleable iron arms were used in both wheel and pinion; but a disagreeable ringing noise was produced, and wheels made wholly of cast iron are therefore preferred.

From the advantages which frictional appliances afford for engaging and disengaging machinery whilst in motion, a great many reversing and clutching movements are obtained, as also many simple methods of increasing or diminishing the speed, which are not practicable with toothed gearing. Several of these movements are in operation on lathes, and screwing and planing machines. The variations of which they are susceptible appear endless, and if once introduced to spinning and other arts no doubt many useful applications will be brought forward.

Mr. Robertson exhibited a number of specimens of the grooved surface gearing, consisting of spur and bevil wheels, and wheels for reversing the direction of motion; also speed rings for raising a high speed without the disadvantage of a very small pulley. He also showed the testing machine described in the paper, for measuring the pressure required upon the journals of a pair of wheels in order to obtain a given power of adhesion between the grooved surfaces of the wheels.

The Chairman enquired what wheels on this construction were at present in use, and what was the greatest driving power that had been communicated by that plan of gearing.

Mr. Robertson replied that there were as yet not many at work, about a dozen applications in all; six of these were reversing movements for screwing machines and screw cutting lathes, and one was on a planing machine. A pair of bevil wheels were at work, the pinion 1 foot and the wheel 3 feet diameter, transmitting about four horse power. The largest size yet employed was a wheel of 8 feet diameter gearing into a pinion one half that size; the wheels were communicating from 16 to 18 horse power, driving the lathes, blast fan, and other machinery in an engine shop. It was only three months since the plan had been tried for large wheels, and at first only small applications were thought of; but he expected now that the construction would do for any size or power, and would be found superior for a great many purposes to either toothed gearing or straps.

Mr. Fairbairn doubted whether there would be any advantage over toothed wheels, in consequence of loss of power from friction; he was inclined to think there would be less friction with toothed wheels well formed with the correct epicycloid curve for the teeth, and that there would be greater friction on the bearings with grooved wheels, owing to the amount of pressure required to give the necessary adhesion. He considered the system of toothed gearing had hitherto been found better than straps or other frictional means.

Mr. Robertson thought the objection generally felt to driving by means of friction arose from the experience of plain surfaces, as in the case of railway driving wheels, where a great pressure was required to get the necessary adhesion; but he had found that the grooved surfaces required only about $\frac{1}{5}$th of the pressure of plain surfaces to give the same amount of adhesion for driving. In the testing machine when the top wheel weighing 106 lbs. was resting with its weight on the lower wheel, the bearings being clear from the shaft, a force of

159 lbs. acting on the circumference of the upper wheel was necessary to make them slip.

The Chairman asked whether the grooved-surface wheels had been tried at any very high velocities. He had seen in America belts driven as high as 5000 feet per minute; and he thought the grooved gearing appeared likely to answer well for such high velocities from the smoothness of its motion.

Mr. Robertson said the 8 feet wheel working in Glasgow was running at 50 revolutions per minute, making a speed of 1250 feet per minute at the circumference; and a speed ring 13 inches diameter was working on a 7½ inch pulley driving a fan at 1400 revolutions per minute, or about 2750 feet per minute at the circumference.

Mr. Scott Russell thought the plan a valuable invention, as well as very ingenious; he was much struck with the steady practical way in which the idea had been prosecuted and worked out step by step. The adoption of wedge-shaped grooves was certainly an improvement over the use of plain surfaces for friction, being attended with the advantage of the wedge in increasing the pressure between the surfaces without increasing the pressure upon the centres of the wheels; an additional hold was thus gained, from the surfaces wedging one into the other. His impression was that if the wheels were of very large size, as for the gearing of a large screw propeller, the bite would hardly be sufficient to withstand the hard thumps of a sea-going screw, and that toothed gearing would still be necessary in such cases; he hoped however that experiments on the application of the plan would be persevered in for every kind of gearing on a small scale, as the principle involved was so good that it might prove more generally applicable than was apparent at first sight. The contrivance for obtaining a high speed by means of the intermediate speed ring, without requiring a small sized belt pulley, was beautifully carried out, and would be valuable in preventing the wear and friction of a strap working on a small pulley. He enquired whether the loose ring was found to work steadily upon the small pinion.

Mr. Robertson had feared at first that the ring would not work steadily, but he found that the tension of the strap was sufficient to hold it steady, while running at any speed, and the motion was remarkably smooth and easy.

Mr. Fairbairn observed that each pair of grooves could be in contact theoretically only in one line in the line of centres, and therefore must have a very severe pressure at that point in order to communicate any high amount of driving power.

Mr. Robertson had thought so at first, and had consequently contemplated applying the grooved gearing to transmit a small power only, but he had since changed his view, from the results of actual working. He found that the grooves soon wore themselves to smooth surfaces after starting, and then there was not any further wear perceptible. With very deep grooves a different action might occur; but it appeared that grooves of only ½ inch pitch and proportionate depth were sufficient for the heaviest gearing. It must be observed that there was a large amount of slip in toothed wheels, amounting to 16 feet total length of slip in one revolution of a wheel of 8 feet diameter with cogs of 3 inches pitch; but there was only about one inch length of slip with a grooved wheel of the same size with grooves of ½ inch pitch. He wished that more complete experiments were tried upon toothed wheels, to ascertain the amount of power lost by friction between the teeth and pressure upon the journals, in order that a complete comparison might be made.

Mr. Harvey thought that toothed wheels were objectionable, where liable to sudden heavy strains; and it was advantageous to get the wheels to slip, when the strain became too great and risked the fracture of the teeth, as in the gearing of large steamers in a heavy sea, so that they might hold only up to a certain amount of power, and beyond that strain be sure to slip. In the centrifugal drying machines, which were driven at a very high speed, it was necessary to drive by cones, in order to get up the speed gradually; but when smooth cones were used they were found to slip, and they were afterwards covered with leather, to obtain the effect of the imperceptible teeth of the leather; but as the leather got worn, it soon became too smooth to drive, plain surfaces only being in contact.

Mr. Siemens thought the objection of rapid wear that had been raised to the friction of the grooved-surface wheels was less important in practice than might appear at first. The surfaces in contact at each groove were two cones, and if absolutely hard they could be strictly in contact only in a line, and only for a moment in passing the line of centres, and consequently the slip during that momentary contact would become indefinitely small. But if the surfaces were elastic, they would remain in contact for some appreciable time, and would then appreciably slip during contact from the angular motion of the two surfaces in opposite directions. Cast iron however being very hard would have very little yielding, and consequently there could be only very slight friction in the grooves, when they were no deeper than shown in the drawing.

Mr. McFarlane asked whether the grooves required oiling, when there was much friction between the wheels; if there were not a large rubbing surface he thought the grooves would soon wear away, and get to bottom in one another.

Mr. Robertson said the grooves were not oiled at all; but they were not found to wear perceptibly if the necessary breadth of wheel was given, after once assuming a smooth polished surface, which soon took place after setting them to work.

The Chairman observed that the circumstance of the grooves being found to become polished on the surface in the course of work showed the existence of friction between them. The action was somewhat similar to that of a roller working against the sides of the thread of a screw and traversing longitudinally along the screw, which he had applied and found to work with little wear. His impression was that for high velocities the grooved-surface gearing was likely to be very valuable.

He proposed a vote of thanks, which was passed, to Mr. Robertson, for his paper and the numerous specimens that he had exhibited.

The following Paper, by Mr. John Stephen, of Glasgow, was then read :—

DESCRIPTION OF A STEAM BOILER WITH COMBINED INTERNAL AND EXTERNAL FURNACES.

There are two modes of firing boilers at present in use; one consisting in firing by means of an external furnace placed under the bottom of the boiler, as in the original waggon boiler, and in some examples of its successor, the cylindrical boiler, sometimes with and sometimes without return flues passing through the water space of the boiler; whilst in the other mode the boiler is fired by means of a furnace in an internal flue, the flames and heated gases returning under and along the sides of the boiler, as in the Cornish and other boilers.

In the boiler forming the subject of this paper, both these plans are combined, and the heating and evaporating effect is thereby concentrated, whilst space is economised and the size and cost of the boiler itself is reduced; or in other words, the same boiler is made to do so much more work.

The mode of working out the improvement in practice is shown in Figs. 1, 2, and 3, Plate 81. Fig. 1 is a longitudinal section of the end of the boiler at which the furnaces are placed, showing the arrangements for firing the two sets of furnaces; Fig. 2 is a sectional plan of the boiler; and Fig. 3 is a transverse section.

The boiler is of the ordinary cylindrical shape with flat ends and gusset stays. There are two internal flues AA with grates at their front ends. These flues unite in a central single combustion chamber B at the back of the fire bridges, and again diverge behind the chamber, as shown in the plan Fig. 2. They may however, instead of diverging, be continued in one large flue to the end of the boiler; or if preferred for greater strength, the two flues may be carried straight through to the end of the boiler before uniting. Two corresponding furnaces CC are placed under the boiler, being separated either by a brick partition, or as is preferred by a water space D, as shown in Fig. 3. The flues of the upper and lower right hand fires unite at the back end of the boiler, and communicate with a flue E returning along that side of the boiler to the front. The flue E communicates with a second flue F above it, passing back again to the back end of the boiler. A similar arrangement of the flues is adopted at the left hand side of the boiler, and the two upper flues F unite at the back, and their contents pass thence to the chimney. The two upper furnaces are fired alternately, as are also the two lower ones, by which means the consumption of the smoke is very thoroughly effected. The upper internal furnaces are fired from a stage G, on a level with the bottom of the internal flues A, so that the ashpits of the upper furnaces can be cleared out upon the stage.

An important practical advantage affecting the durability of the boiler arises from the external shell of the boiler and the casings of the internal flues being heated equally and expanding equally and together, instead of being unequally strained as in the ordinary kinds of boilers before referred to. When an external fire only is used, the bottom of the boiler is much hotter than the flue, if there is an internal flue; whilst when an internal fire only is used, the flue is much hotter than the outer shell; and the unequal expansion of these parts gives rise to a severe strain tending to tear them asunder every time steam is raised. The effect of such repeated unequal expansions and contractions is to loosen the rivetting of the plates and angle irons, and to injure seriously the strength and durability of the boiler. The difference of temperature which must exist in this way between the internal flue and the outer shell of an ordinary boiler will cause a palpable difference in the length of these parts in the case of a boiler of moderate length such as 35 feet.

With the new arrangement of steam boiler which has been described is also combined a self-acting boiler feed apparatus, consisting of pumps worked by a pair of small donkey engines. The steam valve of these engines is opened on the descent of a float within the boiler, when the water level gets low, the float acting on the valve by means of a rod passing through a stuffing box in the boiler shell. The two steam pistons are connected to cranks at right angles to each other upon a shaft carrying a small flywheel, so that the engines can start at any time, in whatever position they may have stopped when last working.

In fitting up the improved boilers, it is usual to arrange in connection with them a self-acting damper adjuster, which was introduced some years ago by Mr. Auld, one of the inventors of the present boiler, and has been long in extensive and successful operation. In this apparatus the steam from the boilers is made to act upon a column of water, which supports a float connected with the chimney damper. When the steam pressure exceeds a determined amount, it passes through a loaded valve, and causes the column of water to raise the float and close the damper; this reduces the furnace action and brings down the steam within proper limits. On the steam pressure getting too low, the reverse action takes place. In adapting this apparatus to the improved boilers, it is made to act not only on the dampers, but also on air valves, which admit air through passages running along the sides of the external furnaces, the air being delivered into the flues at the furnace bridges. The flues of the four furnaces being combined in the manner described, and the furnaces being fired alternately or in rotation, the supply of air may be uniform, or varied only in so far as the chimney draught itself causes it to vary with a uniform aperture. The object of the above arrangement however is to reduce the air supply when the damper is partially closed and the furnace action restrained, and to increase it on the contrary when the damper is opened and combustion goes on more rapidly, when more air is obviously required.

Mr. Stephen explained that his object had been to erect a boiler that would do 1½ or 2 times as much work as an ordinary boiler in supplying steam, without occupying more space, and at the same time with an economical consumption of fuel. There were now two of the boilers at work, of 7 feet and 8 feet diameter, which had been found very satisfactory in raising steam; but there had been no means at present of working them separately, so as to ascertain the exact consumption of fuel in either case.

Mr. Dunn believed a boiler very similar in arrangement to the one that had been described was at work in Manchester, and understood the results were highly spoken of.

Mr. Fairbairn thought that the boiler plates at the junction of the two flues would be found difficult to keep in order, on account of the flame of the two furnaces impinging so forcibly on that part.

Mr. Johnstone considered the water space below between the fires would be very liable to burn, from the collection of sediment that would take place in it and the imperfect supply of water; a fire brick partition between the fires would be preferable, though certainly liable to burn away quicker than the rest of the boiler setting.

Mr. **Harvey** thought there might be an advantage in the boiler for some situations; and a brick partition or water space would be of use in dividing some wide furnaces into two portions, to be fired alternately; he had known a case of this being done with an improvement in economy of fuel. However as a means of carrying off the heat from the bottom of the boiler, a great advantage over the brick partition would be obtained by the water space represented as dividing the two lower fires, the bottom of which forming a pocket below the fire bars would thus become a receptacle for all deposit, from which by a blow-off cock it could be carried away at convenient seasons.

A vote of thanks was passed to Mr. Stephen for his paper.

The following Paper, by Mr. Michael Scott, of London, was then read :—

DESCRIPTION OF AN IMPROVED LADDER FOR DREDGING MACHINES.

In the course of operations undertaken with the view of improving the harbour of Blyth, in the county of Northumberland, it became necessary to remove from the bed of the river some very obdurate material, consisting of boulder gravel, rotten rock, and very tenacious clay with boulder stones in it. A breakwater is in progress, but it is not sufficiently advanced to afford protection from the swell of the German Ocean; and during spring tides there is a very rapid stream in the channel of the river.

As it was considered that the above material could be removed only by dredging, a single machine was procured, the ladder of which was formed of timber strongly put together and trussed with tension rods underneath. Very soon after this machine was set to work, the ladder got strained, and ultimately gave way at the distance of about one third the length from the lower end. It was carefully repaired, new timbers put in, and plates of iron added on each side, the whole being strongly bolted together; but in vain, for it broke a second time. As it was now evident that a new ladder must be provided, the first step to be taken was to make enquiry as to the construction and strength of ladders employed elsewhere; and attention was naturally first directed to the Clyde, where dredging operations of such extraordinary extent have been carried on; but the writer was informed that both there and elsewhere the ladders were formed of timber, some being plated with iron. Feeling convinced however that this mode of construction would not bear the strains to which the Blyth machine was exposed, he devised the arrangement forming the subject of this paper, which has proved quite successful.

In investigating the causes of the breakage of the original ladder, it appeared to arise chiefly from lateral weakness; for when the machine was at work, and the lower end of the ladder in the bottom of the trench formed by the working of the machine was pressing the buckets against the face of the bank, if whilst in this position a beam swell came against the vessel so as to move her sideways, then the ladder broke at that part where it came in contact with the bottom of the side of the well in the dredger. It therefore became a primary condition that the new ladder should possess great lateral strength. The other leading conditions were obviously—that the ladder should have vertical strength sufficient to carry the chain of buckets with their load;—that it should be sufficiently rigid;—that it should be capable of resisting compression in the direction of its length;—that there should be a free passage for stones, &c., falling out of the buckets when over full;—that the ladder should be durable under the influence of sea water;—and lastly, that it should not be over heavy so as injuriously to affect the displacement of the vessel.

In attempting to fulfil these conditions, several arrangements of material suggested themselves. If the body of the ladder were formed wholly of timber, it appeared difficult to obtain the necessary strength combined with a free exit for the stones, &c. Again, if the ladder were made in the form of a wrought iron girder and of thick plate, it would be too heavy; if of thin plate, there would be danger of the upper flange buckling; and if with a cellular top, then the cells would be too small to admit of painting the interior, and the ladder would suffer from oxidation.

For these reasons the writer decided upon adopting the construction shown in Figs. 1, 2, and 3, Plate 82.

Fig. 1 is a side elevation of the new ladder. Fig. 2 is a plan, part showing the rollers for carrying the chain and buckets, and part with the rollers removed. Fig. 3 is a transverse section of the ladder to a larger scale, and Fig. 4 a side elevation. Figs. 5 and 6 show the general position of the ladder in the dredger when at work.

The ladder consists first of a tubular wrought iron girder A, composed throughout of plates $\frac{1}{4}$ inch thick rivetted together with suitable angle irons and covering pieces. The spaces formed by the projection of the upper and lower flanges are occupied by two beams of timber B secured by bolts both to the webs and flanges. At each end of the ladder are strong wrought iron straps C, rivetted to the plates and bolted through both plates and timber; these straps or jaws carry the plummer blocks D in which the tumblers E work, and it should be noticed that the inner set of these blocks bear against the ends of the timber beams B, with which they are kept in contact by cotters acting upon the outer blocks. After the beams were fitted into their places, the plates F were rivetted on outside them, the angle irons above and below being bent so as to prevent them from catching the sides of the well G of the dredger, when the ladder is lowered or raised. Underneath the body of the ladder are wrought iron struts H and tie rods I, forming a truss of the ordinary kind. There are openings K in the top and bottom plates of the girder A to permit stones, &c., falling out of the buckets to escape, the upper opening being perpendicular over the lower when the ladder is at an average working inclination.

It is submitted that several advantages are obtained by adopting this form of ladder :—

Firstly, vertical strength : assuming the body of the girder to constitute a sufficient upper flange to resist compression, the sectional area of the iron plates alone being more than three times that of the tie rods, and therefore considering the strength of the ladder to be limited by the tensile strength of the tie rods, the vertical strength of the ladder calculated from the sectional area of tie rods would be nearly five times the greatest weight ever put upon it, which will not exceed 14½ tons distributed load, including the weight of the ladder. For, the sectional area of the tie rods which form the lower flange is 7 square inches; the distance between the supports, or the length of the girder, is 56 feet; the depth of the girder from centre to centre of flanges is 3½ feet. Hence, taking the tensile breaking weight of wrought iron bars at 20 tons per square inch, the breaking weight would be 35 tons in the middle of the girder, or 70 tons distributed over the entire length of the ladder.

Secondly, lateral strength : assuming the ladder to be laid on its side, and considering the strength to be limited by the tensile strength of the bottom flange, the lateral strength of the ladder calculated from the area of the bottom flange would amount to a breaking weight in the centre of 36 tons. Thus, the sectional area of the iron plates constituting the bottom flange is 8½ square inches; the length as before 56 feet; the depth 3 feet. Then, taking the ultimate tensile strength of wrought iron as before at 20 tons per square inch, the breaking weight in the middle of the girder would be 36 tons.

Thirdly, the form here adopted affords considerable rigidity and power to resist compression in the direction of its length.

Fourthly, the new ladder is much superior to the old one in the facility which it affords for stones, &c., falling out of the buckets to escape.

Fifthly, it is expected to be durable; for there is no part of the surface exposed to the action of the water which is not readily accessible for painting.

Lastly, this ladder was easily and quickly made, and at a moderate cost.

The new ladder has now been at work for about two months, working most of the time during the night as well as by day; it has been severely tested; and having proved successful, the writer has submitted the above description of it to the Institution.

Mr. Scott observed that the special reason for making the ladder of the dredging machine so strong was that, when imbedded in stones at the lower end, the shifting or heaving of the dredger caused a severe lateral strain acting at a long leverage.

Mr. Fairbairn remarked that the ladder formed a complete wrought iron girder, combining great strength with lightness, and it appeared well designed for the purpose.

Mr. Scott said the strength of the ladder had been severely tested by an accidental fall, that had occurred when it was resting on the dredger at one end and elevated 20 feet above the ground at the other end; the suspending chain broke, and the ladder fell on one end, but did not sustain any injury.

The Chairman enquired what length of time the new ladder had at present been at work.

Mr. Scott replied that the ladder had been in constant work night and day for two months, and had stood the work quite satisfactorily; its durability was now a question chiefly of oxidation. He did not think it would be possible to combine timber so as to give sufficient strength for the purpose, as the resistance to be overcome was so great; the rocky material lifted by the dredger was so hard as to tear the steel off the edges of many of the buckets in two months. The ladder was constructed with a small expenditure of material, and was not more expensive than one of timber; and the whole was made in about thirty days.

The Chairman proposed a vote of thanks to Mr. Scott for his paper, which was passed.

The following Paper, by M. Pietro Conti, Commissioner of the Sardinian Government was then read :—

ON A NEW CONSTRUCTION OF IRON SHIPS FOR WAR PURPOSES

The important experiments made at Liverpool and Woolwich by the most learned and competent authorities, on the resistance of iron plates to shots, having given an unfavorable result, the author feels that the title of this paper must appear somewhat strange. However, as the principle of construction now proposed is essentially different from all those hitherto tried, he hopes that it will not be thought undeserving of consideration and discussion.

The use of iron in the construction of vessels, which is a subject demanding more or less the attention of all the nations surrounded by sea, is of the greatest importance to the author's country. A destructive insect, unfortunately not altogether unknown in England, does most serious injury to the timber and ships lying in the Sardinian docks and arsenals, in consequence of which the time they will remain in good condition and fit for effective service is considerably shortened, causing a great expense, and rendering it almost impossible to keep a large fleet, not from the first cost, which the country would willingly undertake in order to put the navy in the desired state of efficiency, but from the enormous expense necessary to maintain it always in the same condition, when the materials have so short a duration.

It has been proved by the above named experiments that iron plates are not only easily pierced by point-blank shot, but that the greater the distance from which the shot is fired and the less its force, the greater is the damage produced by it in the ship's wall, especially in the side first receiving the shot, which is not pierced with a clean opening, but torn out or shattered over a large space, so that it is almost impossible to stop the hole and there is great danger of the vessel being sunk. Even the floating batteries, strong as they are, cannot resist the heaviest shot; and the construction of a frigate on that system would from the weight and expense be out of the question.

But although it would be impossible to construct a large vessel on the plan of the floating batteries, these may still afford some useful hints. The bottom of the ship, which is the most expensive part and the most subject to humidity, dry rot, &c., can be made, as in them, of iron up to the depth of penetration of the shot in the water; a large frigate can thus have nearly half the total height constructed of iron in the usual manner. The feasibility of this plan is proved by the success which has attended its adoption in the construction of the floating batteries. For the remaining part of the ship which is exposed to shot the author's idea is not to endeavour to resist the shot, but to let it pass through, with at least as little injury to the sides of the ship and the persons on board and as great facility for stopping the hole as in common wooden men-of-war; and he thinks that in the proposed plan, if other peculiar considerations do not interfere, there will be much greater facility for repairing the effects of the shot.

It is evident that if it were possible to have, above the line of penetration of shot, iron frames so constructed and arranged as to be protected from the effect of shot, and at the same time to have the sides of the vessel made of common planks easily worked, placed, repaired and fastened to the iron frames, the proposed object would be then attained. Moreover if in the course of a shot there is a fixed obstacle acting as an inclined plane, it is well known that the shot is diverted to a considerable angle from its original direction. A very striking instance of such an effect is in the deviation caused in the course of a rifle bullet by the bones of a man's body; a bullet can pierce the skin, and, although the angle of incidence made by its direction with the tangent to the rib bones be not very small, the bullet is deviated and travels between the bones and the skin for a considerable distance. The author is personally acquainted with several of these cases.

These considerations have led the author to propose the following mode of construction. The frame work of the ship is made of angle iron in the ordinary manner below the line of penetration A, Fig. 1, Plate 81. Above that line the frames have a prismatic form, as shown enlarged in Fig. 3, BB, their horizontal section being a triangle with its vertex C towards the outside plank D forming the ship's wall. If a shot strike the frame on the inclined sides B, it will be diverted from its direction by these inclined planes, and the only destroyed parts will be the planks D and E. The shot passing through the planks will strike the other side of the ship; and to provide against the breakage of the frames on that side, they must present there also the same cause of deviation to the shot. This is effected by adding the inverted inside pieces F, which are fastened to the frame B by the cotters G. The shot being diverted by the frame first struck cannot strike the inside piece F of the opposite frame on the vertex H in the direction of the centre line of the frame so as to have its full destructive effect; but if the shot strike the outside frame on the vertex C, then it will have its full effect and cause a breakage of the frame. To prevent this result, the square-sectioned bolts I are employed, the heads of which are made in the form of inclined planes similar to the sides B of the frames, the middle of the inclined plane covering exactly the vertex C of the frame, which thus can be struck only in the safe parts and is completely protected. The bolts I serve at the same time to fasten the outside planks D forming the walls of the ship to the frame B, to which they are strongly fixed by cotters. If the shot strike the bolt head on the vertex, the head will most probably be wrenched round, turning on the inner corner which is made re-entering for the purpose, or it will be crushed altogether; but the shot will never strike the vertex C of the frame. The head of the bolt is lengthened with the same shape above and below the centre of the bolt, as shown dotted in Fig. 1, so as to fill up the distance between the adjacent bolts, and thus the bolt heads protect the entire vertex of the frame.

The bolts I are easily replaced if injured, and the damaged planks D also; but for the purpose of stopping up a hole very quickly, and indeed almost in a few seconds, the inside planks E are employed, supported against the pressure of the water by the faces B of the frames. When a hole has been made by a shot in the side of the vessel composed of the outside planks D and the inside planks E, as in Fig. 2, to stop the hole it is only necessary to remove the broken pieces E and slide down two or three of the pieces above, which stop the large hole; and the seams being then caulked all round, the water is effectually prevented from entering, no matter how irregular was the hole made by the shot. After the action, it is a very simple and inexpensive matter to replace the damaged outside planks D between the scarfs K. In this manner the parts which are essential to strength, namely the frames, are always free from injury and of very durable material; while the wooden part is composed of distinct pieces, of short length and without curvature, being therefore of little cost, easily fixed, and lasting a greater length of time.

The arrangement of the inside pieces F not only causes the deviation of the shot coming from the opposite side, but also strengthens the frame between the decks, being fastened securely to the frame by the cotters G; and if in an extraordinary case a frame should be broken, they afford the means of quickly repairing the broken part in a strong manner. Two screw-jacks might be placed against the nearest stanchion, one at its foot and one at its head, converging against the two separated ends of the broken frame just near the point of rupture, and by the action of the screw-jacks the two separated parts of the frame would be brought back into contact; and having removed the broken inside piece, a new one of the same form could be connected to the broken frame with cotters, for which some holes should be prepared beforehand and kept not filled.

With regard to the resistance offered by this plan of construction to the action of a heavy sea, the bottom of the vessel up to the line of penetration of shot may be made as strong as possible with keelsons and bulkheads, &c.; above that line the general system is that of a series of tubes, of nearly rectangular section, formed by the sides of the ship and the decks. The transverse beams L carrying the decks can be strongly rivetted to the frames, into which their ends can enter so as to make one strong frame-work; and the several frames are kept at the proper distance apart by the planks D and E, and also by the longitudinal stringer-plates M rivetted to the angle-iron of the beams L and also to the frames. The beams L are also supported by stanchions in the ordinary manner, which thus give greater rigidity to the structure.

Mr. **Fothergill** enquired whether any experiments had been made on the breaking or resisting power of such frames as were described in the paper.

M. **Conti** said he had not had an opportunity yet of making any experiments; he had been long giving much consideration to the subject, and now proposed this mode of accomplishing the object.

Mr. **James R. Napier** said that M. Conti had applied to him for information on the subject of the proposed construction for war vessels; but as he had not any personal experience of the effects of shot upon materials, which was the particular point considered in his plan, he had referred him to the Institution for information.

Mr. **Fairbairn** mentioned that at the Admiralty experiments, made ten or twelve years ago at Woolwich Arsenal, at which he was present, the effect of iron shot was tried, fired against wrought iron plates from ¾ inch to 2 inches thick, point-blank and at different degrees of obliquity; and the curious fact was ascertained that a 36 lbs. shot, fired at 100 yards range with a charge of 5 lbs. of powder, went through a ¾ inch plate, leaving a hole quite round; but with a small charge of powder, the same shot tore up the joints of the plates all round, causing extensive damage in a direction that would prove highly injurious to the sides of an iron ship. A plate 2 inches thick broke the shot to pieces, and sometimes the plates were also fractured by the concussion. From the effect of spent shot on iron, it was then supposed that more injury would be sustained by an iron than a wood ship, the iron being broken into a great number of pieces, scattering dangerous splinters in every direction. The 4½ inch plates used in the recent gun-boats split the heavy shot all to pieces; but with the great wrought iron gun lately made at Liverpool even that thickness of plate had been split.

The mode of construction proposed by M. Conti appeared theoretically an ingenious plan for diminishing the injury done to ships by shot, and might lead to some important improvements. He feared that if a shot were to come in contact with one of the bolts, the effect might be to throw the shot obliquely across the deck.

M. **Conti** remarked that they were always liable to oblique shot over the decks, and a vessel was always kept as far as possible from a position exposed to receiving a broadside.

The **Chairman** proposed a vote of thanks to M. Conti for his paper, which was passed.

The following Paper, by Mr. Robert C. Ross, of Glasgow, was then read:—

DESCRIPTION OF A NEW MACHINE FOR CUTTING AND FORGING FILES.

The subject of the present paper is the application of machinery to forging and cutting files. Amongst engineers and machinists, files as common edge tools are about the most expensive in the trade, first from their general and extensive use, and next from the great difference of cost between the finished tool and the material from which it is manufactured, arising from the extra amount of labour required to produce the files, the greatest part of which is expended on the teething of the files or blanks. It may therefore naturally be inferred that machinery brought to bear on this branch of manufacture will be of considerable advantage; and accordingly many machines have been constructed for this purpose, although hitherto they have not been brought to any really productive results.

The chief difficulty in the application of machinery for file cutting appears to have been the want of a proper modification of blow, suitable to the various depths of cut and breadths of the file required; and also the proper adaptation of the teething tool, so that it may be steady in its action in the direction of the length of the file, and at the same time free to follow the transverse variations which occur when the tool is held at an angle across the taper part of the file, or any other variations which may occur, the files being often very far from level.

In the machine described in the present paper, and shown in Plates 83 and 84, as now applied by the writer for file cutting, the action in hand cutting has been followed as closely as possible. The machine consists of a hammer for striking, mounted in a cast iron frame, working in connection with an arm for holding the tool; the hammer as striker and the arm as toolholder are fixed in the framework in the same relative position as the striking and holding arms of a man while in the act of cutting a file by hand.

Fig. 1, Plate 83, is a side elevation of the new machine; Fig. 2 is a front elevation, and Fig. 3 a back elevation.

Fig. 4, Plate 84, is a side elevation of the principal parts of the machine to a double scale, the framework and handles in front being removed where necessary. Fig. 5 is a plan of the toolholder and tool for cutting the teeth, and Fig. 6 is a transverse vertical section of the same.

The arm or toolholder A, Figs 1 and 4, is suspended in centres B in the framework C, the centres being arranged to work in slots in which they are adjusted by means of set screws, in order that the arm and tool may be conveniently adjusted to any inclination required. The lifting motion of the arm is imparted to it by an eccentric D on the driven shaft, acting upon a curved lever E bolted to the arm A. The hammer and lever F are mounted in the frame C on suspension centres G, at the necessary height above the arm A to correspond with the inclination of the chisel or tool, it being necessary that the hammer should fall at the same inclination at which the tool is held. The lever F is worked by a vertically acting cam H, imparting to the hammer the required rise and fall for the blow.

The tool or chisel I is fixed in a moveable round block of iron J, Fig. 5, into which two double centres are inserted, the one centre resting in the tool and toolholder, and the other in the moveable block and toolholder; the centres are adjusted by a wedge or cotter acting on a slip of steel K turning on a pin joint, into which one of the centres is inserted. The tool by this means is kept steady in the direction of the length of the file L; and at the same time is allowed to turn or rock on the centres, so that it may at all times come fair to the face of the file, independent of all transverse irregularities that may occur in the file to be cut. These irregularities of surface are chiefly felt at the point of the file, where, in consequence of the oblique position of the tool across the file, the varying thickness or taper of the file exposes a varying surface in proportion to the horizontal angle of the tool across the file or the obliquity of the cut; the one side of the tool being nearer the point of the file than the other, and consequently on a thinner part of the file, the difference in thickness of course increasing as the taper of the file increases. The arm A carrying the tool I is brought down on the file L by means of a pair of springs M, one on each side of the machine, which keep the curved lever E constantly pressing against the eccentric D. There is also a hand lever N on each side of the machine, connected to the tool I by a joint rod to which a spiral spring is attached, which brings the tool I and arm A down on the file L, and at the same time commands the tool on the turning centres, so as to bring it at all times fair to the face of the file.

For the purpose of making the reverse oblique cuts on the file during the return course, the tool I is turned round in the toolholder after the first course, so as to reverse the obliquity of the cut to the extent required, and adjusted firmly in the new position by means of the cotter and jointed slip of steel K in the toolholder A, changing the position of the turning centres from 1—1 to 2—2, Fig. 5.

The modification of blow given by the hammer is accomplished by means of a vertical bar O, resting on the top of a spiral spring P, and sliding upon a guide rod which rocks upon pivots at the bottom of the machine, as seen in the back elevation, Fig 3. The spring P exerts its elastic force through the sliding bar O on the underside of the lever F on which the hammer is fixed. The sliding bar O is shifted in front of or behind the suspension centre G of the lever F by means of the crank arm Q worked by the hand lever R. The elastic force of the spring is thus made to regulate the force of the blow in different degrees in proportion to the distance of the point of action of the spring on either side of the suspension centre G. If moved to the extreme distance in front of the suspension centre G, as shown by the dotted lines in Fig. 4, the hammer will be completely poised and prevented from striking; and if moved to the extreme distance behind the centre, as shown by the full lines in Fig.4, the hammer will strike with its greatest force, the recoil of the spring P being then added to the force of the hammer in falling; at any point between these two extreme positions the effect of the blow will be proportionate to the distance at which the spring acts in front of or behind the suspension centre G. By this arrangement ment the force of the blow struck by the hammer is completely under the control of the person in charge of the machine by the adjustment of the hand lever R.

The file L to be cut is fixed by the tang upon the cast iron block S which slides on a horizontal bed on the framework C; beneath the file there is a bed of lead or composition to preserve the teeth on one side from injury while the other side is being cut. The file is also held down on the block S by a binding roller T, carried in a frame sliding vertically upon the framework of the machine, and pressed firmly down by a plate spring U, which is held down by a pin inserted in a series of holes in a circular arm V, so as to afford the means of adjusting the pressure; the roller T is thus made to bear with uniform pressure on the surface of the file close to the cutting edge of the tool I. The roller by the pressure of the spring

U binds the cast iron block S to the frame of the machine, and likewise the file to the block, thereby ensuring a solid blow.

The binding roller T also serves the purpose of filing after the first cut, a process which is adopted in hand cutting to smooth down any irregularities that may arise from what is termed the first course, the roller being hard and pressed firmly down on the file whilst traversing its entire length answers the above purpose of filing or smoothing in the machine, and also saves time.

The feed motion between each blow of the hammer is imparted to the block S carrying the file by means of two stampers W attached to the back end of the hammer lever F; by the depression of this end of the lever the stampers communicate motion by means of a screw and ratchet wheels to the block S on which the file is fixed. The ratchet wheels act in opposite directions, and the motion of the block S is reversed at the end of each course by means of the handle X, by which one of the stampers W is thrown out of gear and the other into gear. Each depression of the back end of the lever F moves the ratchet wheel one tooth, thereby moving the block S through the necessary distance for each cut to be made in the file, the ratchet wheels being changeable and the number of teeth in the ratchet being proportioned in each case to the pitch of the screw and the number of teeth per inch required for each particular kind of file.

By these arrangements the separate motions of the hammer F and file block S are carried on until the tool I arrives at the end of the file L, when a wedge shaped stud on the end of the block S comes in contact with an adjustable curved bar Y on the hand lever R, and pushes it out laterally so as to liberate it from the notches in the guide Z; the lever R immediately falls, bringing the sliding bar O in front of the suspension centre G of the hammer, and thereby stopping at once the whole movement of the hammer, until another file is fixed and the lever R again brought in gear, when the machine comes into action as before. The machine is stopped in the same manner at the end of the return course. At the point of the file however the boy in charge of the machine generally relieves the lever by hand, in order to regulate the force of the blow at the extreme point of the file, allowing the lever to fall when the file is finished.

One of these machines with the attendance of a boy will cut about four dozen 14 inch files per day, the attendance of the boy costing about 1*s.* 6*d.* The cost of the same amount of labour by hand is from 12*s.* to 14*s.* according to the kind of file, and the time about two days and a half. The files cut by the machine have been tested by many parties and found to be generally equal to the best hand cut files. These machines may be seen in full operation at Messrs. Hetherington's in Glasgow, where they have been working for upwards of six months.

It is considered that this construction of hammer may be adapted with advantage for general light forging, such as files or bolts or any other light work where active striking is principally required, the force of the blow being regulated on the same principle for forging as for file cutting; the lever for regulating the blow may be brought to any position convenient for the workmen employed at the hammer, and may be worked either by foot or hand as desired. A heavy hammer might be controlled by hand on the same principle, and the force of the blow regulated according to the nature of the work to be done.

Mr. Ross exhibited one of the machines, and also a small model showing the application of the principle to forging.

The Chairman enquired whether there were any of the machines in regular work, and what was the finest cut of file made with them.

Mr. Ross replied that there were now six of the machines at work, some of which had been working for eight months; the finest cut of file yet made with them was common-smooth and second-cut, specimens of which were exhibited; but the machines were capable of cutting finer.

Mr. Fothergill asked whether in raising the tooth of the file it was necessary, as had been often asserted, to give a certain back action of the hand in file cutting, which was supposed to present an insurmountable difficulty in attempting to apply machinery to the purpose.

Mr. Ross had not found such an action necessary, and indeed did not see how it could possibly take place, as the man could not draw back the tool while striking. It had been often stated that file cutting required a peculiar turn of the hand, but it appeared to him that this turn could not be given whilst the blow was being struck, otherwise the hand would check the blow; and the tooth could be raised up by the effect of the blow, only to the particular position in which the chisel happened to be at the moment of the blow being struck, which could consequently be correctly effected by a machine.

Mr. **Fothergill** was glad to hear that explanation, as the mechanical operation of cutting files did not appear an exceptional one, that would not admit of being repeated by machinery like other mechanical processes, if suitable means were adopted. Some years ago he had seen a machine near Manchester constructed for the purpose, but it was not quite successful in raising the teeth on the file; and so much difficulty was caused by the file cutters in Sheffield threatening to strike and destroy any machinery introduced introduced into the shops for cutting files, that the plan was not proceeded with; but he trusted all difficulty arising from such mistaken views on the part of the men was now over.

Mr. **Harvey** had seen the machine at work that had been described, and thought it a very ingenious arrangement; it did not seem quite perfect in respect to the chisel, as this appeared only to depress or cut, instead of raising a burr as in hand work; but this was merely a point of detail, that would be rectified by experience, and he thought a properly shaped chisel struck at a sufficient inclination would produce the same effect as the hand chisel.

Mr. **Ross** thought it was not possible to indent the steel with a chisel without raising a burr; if the chisel were made bevel edged, and struck the metal obliquely, it would necessarily drive the material forward, and consequently raise a burr; and the same effect must be produced in the machine as by hand, if the chisel and blow were in the same relative direction in both cases.

Mr. **Neilson** agreed that the machine was very ingenious, but felt strongly of opinion that it would not be quite equal to hand work in throwing up the cut. There would be a difficulty particularly with fine cut files made by the machine, which he thought would have little more than a line or slight groove cut without the necessary burr; and he thought the specimens of fine files exhibited were not quite equal to hand cut files. Some improvement might perhaps be made by an alteration in the form of the chisel, and coarse files certainly presented less difficulty in the use of machinery.

Mr. **Johnstone** thought that there was a good burr shown in the machine cut files exhibited, and that the work was very satisfactory; it did not appear to him inferior to ordinary hand cut files.

Mr. Harvey expected there would be some difficulty in getting so thin an edge of chisel to stand in the machine as was used for very fine hand cut files.

Mr. McFarlane thought that in hand cut files there was sometimes a defect of an opposite nature, the burr being left too high so that it was weak and soon broke down, and the machine would have an advantage of more certain and uniform regulation in this respect.

The Chairman proposed a vote of thanks to Mr. Ross, which was passed, for his paper and the machine and specimens that he had exhibited.

The following Paper, by Mr. Alexander Allan, of Perth, was then read :—

DESCRIPTION OF AN IMPROVED STEAM BOILER FOR LOCOMOTIVE AND OTHER ENGINES.

The improved construction of steam boiler, forming the subject of the present paper, is shown in Figs. 1 to 7, Plate 85.

Fig. 1 is a longitudinal section of a locomotive engine, showing the general arrangement of the boiler and firebox, and the frame and wheels.

Fig. 2 is a longitudinal section of the firebox, to a larger scale.

Fig. 3 shows half a sectional plan of the firebox, and half a plan with the outer shell of the boiler removed.

Fig. 4 is a transverse section in front of the fire grate, showing the tube plate and tubes.

Fig. 5 is a transverse section through the fire grate.

Fig. 6 is an end elevation.

The external casing A of the firebox is cylindrical in form, and rivetted to the barrel of the boiler. The back end plate B is flanged round the entire circumference, and inserted into the external casing A, to which it is rivetted with the flange outwards. The plate B has two openings in it, the upper one C for firing the furnace, and the lower D for regulating the admission of air under the furnace bars, allowing access to the ash space for the removal of ashes, and enabling the fireman to work the damper, &c.; these openings are supplied with doors working on hinges or sliding in grooves. EE are manholes into the interior of the boiler, with suitable covers. F is a receiver for the collection of scale and deposit, and is supplied with a cover and also a screwed plug to facilitate the removal of the deposit. Plugs G are also provided at the end of the boiler for allowing the deposit to be cleared out of the water space below the grate. H is an opening to admit air from the exterior of the boiler, and is supplied with a hinged or sliding damper, arranged to be worked from the foot plate.

The firebox I is cylindrical for the greater part of its length, and enlarged at the front end to the form of the tube plate K, as shown in Figs. 3 and 4, so as to form a combustion chamber and at the same time admit of the greatest possible number of tubes. The front end of the firebox may also be made bell mouthed to the form of the tube plate, as shown in Fig. 7, but the writer prefers the arrangement shown in Figs. 3 and 4. The tube plate K and the end firebox plate L are both flanged and rivetted to the firebox. The firebox is securely held and stayed in position by stays and roof girders. MM are inverted bridges or water spaces rivetted to the cylindrical portion of the firebox, which has holes cut in the roof, as shown in Fig. 3, so as to allow of the admission of water to the bridges M, and the escape of the steam generated in them. These bridges, besides adding to the strength of the firebox and giving additional heating surface, are intended to mix up the flame and smoke from the fresh fuel near the fire door, and deflect it against the red fire.

The fire bridge N is made in two portions; the lower part is a hollow metallic bridge, perforated with holes to admit air, and the upper portion is made of perforated fire bricks or tiles. The air admitted by the holes in the lower part will be heated in passing through the fire brick, and on entering the firebox comes in contact with the smoke and flame deflected by the water spaces M, upon which it acts like a series of blow pipes. The air thus mixing with the flame in the combustion chamber between the fire bridge N and the tube plate K causes the unconsumed gases to ignite before passing through the tubes. A hinged door O is provided at the bottom of the fire bridge, with a handle to work from the foot plate, for the purpose of letting out any ashes that may be drawn over the bridge. P is a hand lever for giving a slight motion to the fire bars, so that a clear fire may be maintained, and the deterioration of the bars by burning prevented; in locomotives the movement may be given to the fire bars by a motion taken from the axle or axle boxes of the engine, according to convenience.

The whole of the boiler and fire box is of wrought iron, excepting the tube plate K, which is of copper. The size of boiler shown in the drawings is 4 feet outside diameter, being made cylindrical throughout and about the same diameter as the width of the outside shell of an ordinary locomotive firebox. The heating surface is about the same as in the ordinary boilers of the same length.

In designing the boiler above described, the object of the writer has been the combination of the following advantages:—a form and arrangement of boiler economical in construction, possessing great strength and lightness, occupying little space, and so constructed that the parts most liable to deterioration can be removed with less labour and cost than in ordinary boilers; having also additional facilities for clearing out the deposit and for the consumption of smoke. With regard to locomotive boilers, a special object has been to allow of any disposition of the wheels, with a view to the best distribution of the weight; and in the boiler now described, the firebox being contained within the cylindrical shell of the boiler, the latter can be carried farther back on the foot plate, and the trailing wheels can be placed below the firebox, as in Fig. 1.

The **Chairman** enquired whether there were any boilers at work on the construction described in the paper.

Mr. **Allan** said that there were not any at work at present.

Mr. **Ramsbottom** asked what was the total area for admission of air into the space below the fire grate.

Mr. **Allan** replied that the opening below the fire bridge was 16 inches wide by 10 inches long, besides the back end door nearly as large, which gave an ample area of opening for the passage of the air through the grate. A larger grate area than usual was adopted for the purpose of burning coal, and by the arrangement of the furnace much of the smoke would be consumed.

Mr. **Fairbairn** enquired whether there was not some danger of burning the portion of the boiler below the ashpan, where the deposit was formed, and where there was only a narrow water space.

Mr. **Allan** explained that the boiler could be readily blown out at the receptacle provided there, so as to prevent accumulation of deposit at that part; and it was not exposed there to the direct heat of the fire, the ashpan being open to the air. There was less obstruction than usual from the stays around the firebox, as they were 7 or 8 inches apart instead of 4 inches, in consequence of the firebox being cylindrical without flat sides.

Mr. **Fothergill** observed that the firebars were placed transversely, and asked whether that arrangement was found as good as the ordinary longitudinal position.

Mr. **Allan** said the firebars were shorter in length when placed transversely; and the clinkers were prevented from adhering to the bars and a clear fire constantly maintained by the vibrating motion given to the bars.

The **Chairman** proposed a vote of thanks to Mr. Allan for his paper, which was passed, and expressed a wish that he would give the results of the boiler, when a trial of it had been made.

The following Paper, by Mr. Walter Neilson, of Glasgow, was then read:—

ON AN IMPROVED LOCOMOTIVE BOILER.

The locomotive boiler, from the very high pressure at which steam is now used, has demanded much attention, in order to obtain a form of great strength and safety. The parallel boiler has of late years been adopted, as giving greater strength in its form and greater durability than the raised firebox form, which latter, although made sufficient by stays, is exposed to constantly varying expansions and strains, leading to leakage at the angles. The parallel form however has the objection, more particularly in large engines where much heating surface is necessary, that the steam space is contracted or limited, besides being much occupied by stays as well as by the steam pipe and regulator. The water level is necessarily high in the boiler, leaving only a small segment of the circular area for the regulation of the proper water line; so that the engine driver has very little variation to work upon between too much water and too little, the former causing the engine to prime, and the latter involving danger of burning the firebox or bursting the boiler.

The boiler described in the present paper, and shown in Figs. 1, 2 and 3, Plate 86, is designed by the writer to obviate this defect; and for this purpose there is added on the top of the boiler a steam chamber A, consisting of a portion of a cylinder of smaller diameter than the barrel of the boiler B, the two cylinders being connected at their junction by a strong diaphragm plate C, forming as it were a common chord to the two circles given by the section of the cylinders, as seen in Fig. 2. By this construction a correct form is obtained, the strength of which is equal to the full resistance of the plates to the internal pressure of steam. It will be observed that no angle iron is used in this construction of boiler, and that the strain is entirely in the direction of the plates.

In order farther to provide against the danger of explosion from overheating the roof of the firebox, in consequence of the water getting too low, which the writer believes is the cause of most explosions, the firebox roof D is depressed in a circular shape, Fig. 1, whereby a more correct form of roof girder or crown stay is obtained, and one which is really the strongest that can be got to support the weight or pressure upon the roof. The ordinary parallel girder is not correct in form, the greatest strain for rupture being across the centre of the firebox roof, where the parallel girder has the least power of resistance. In the new plan of firebox, the circular shape of the roof also gives the plates greater power of resistance, independently of the roof girders. As an additional precaution, the top row of tubes is somewhat raised at the smokebox end. The result of this arrangement is that a considerably greater range of water level is obtained with perfect safety; for in case the water line gets as low as the top of the firebox, the crown will be perfectly safe, and the top row of tubes, at the smokebox end, will first give way; and should the water get lower, the part of the crown first exposed to be heated is the strongest portion, and will stand safely till the tubes burn and give warning of the danger. It may be objected to the depressed firebox crown that it will be more apt to collect deposit than the flat crown; but the writer does not think there need be much apprehension on this point, as there is a free and level communication across the top of the firebox from side to side. It should be remarked however that the locomotive engine is never worked to economy with bad water; and money expended in obtaining proper water is more than compensated for in the saving on the engines and in the safety of the boilers.

Another improvement in the boiler now described consists in an arrangement for using coal instead of coke. In the ordinary firebox the production of gaseous matters from the coal is too rapid to obtain a proper combustion; and even if oxygen is supplied by the admission of air into the firebox, the very great variation of temperature in the furnace, caused by every fresh supply of fuel, renders the complete combustion of the gaseous products very difficult. To get over this difficulty, the back part of the firebox under the door is lined with large fire brick blocks E, having tubular openings through them forming a communication between the interior and exterior of the firebox; in the same manner a bridge F is formed in front of the fire with a similar series of tubular openings through it. The fire brick blocks will become highly heated by the action of the fire, and consequently the air drawn through them will also be highly heated, ready for effecting the combustion of the gases, the moment the air enters the furnace in the form of jets. They also maintain a more equal degree of heat in the furnace at each new supply of fuel, which is of great importance. It is not thought that any difficulty need be anticipated in the fixing and maintaining of the fire brick blocks.

The above construction of boiler is expected to afford a more steady supply of steam, and also to give the engine driver better opportunity of working the fire with economy of fuel.

Professor **Rankine** said in the unavoidable absence of Mr. Neilson he had been requested to give any requisite explanations respecting the paper. He observed that the principal object had been to prevent the failure of the roof of the firebox, as the result of such an accident was very serious and generally fatal, whilst the failure of the other portion of the boiler, the tubes, seldom caused more than delay. He had been struck with the importance of the subject by seeing recently the result of the failure of a firebox with a level top, where all the roof girders broke across the top, two only of the girders having been notched at that part. An exactly similar firebox was tested with water pressure, and it was found that 470 lbs. pressure per square inch was required to make the roof give way in a similar manner, being nearly five times the working pressure; that pressure however must have been attained in the case of the accident referred to. The object of the plan now proposed was both to strengthen the roof by giving it a curved form and increasing the depth of the girders, and to protect it by preventing it from being laid bare of water in the centre, leaving the tubes to be first exposed when the water got low. He now suggested the slightly curving the roof in a convex form transversely, to give the deposit a tendency to clear itself at the sides.

Mr. **Fenton** observed that it was very unusual for a failure of the roof girders to occur; when the roof of a firebox had given way, it had generally come down in one piece, with the roof girders entire. The case that had been referred to was the only instance he believed on record of a roof failing across, and in that case there were also no stays from the roof up to the outer shell. A supplementary steam chamber as proposed in the paper might perhaps have some advantage, and he remembered several being so constructed under his superintendence for the Hanoverian Railway.

Mr. **Tosh** had found great difficulty in preventing an injurious accumulation of sediment on flat roofed fireboxes, even with 1½ inch water spaces between the copper roof and the roof bars; any hollow form of roof must increase the evil, and he thought that such a roof would be found very troublesome in practice.

A vote of thanks was proposed and passed to Mr. Neilson for his paper.

The following Paper, by Mr. James Wallace, Jun., of Glasgow, was then read:—

DESCRIPTION OF A STEAM DASH WHEEL FOR BLEACHING.

The object of the improvements described in the present paper is to render the dash wheel more extensively available as a bleaching and cleansing agent for textile fabrics and other materials than it has hitherto been.

The steam dash wheel is shown in Figs. 1 and 2, Plate 87 ; Fig. 1 shows half an elevation and half a transverse section, and Fig. 2 is a longitudinal section of the dash wheel.

The dash wheel A, which in its general features is constructed like those hitherto in use, is mounted upon a hollow shaft B, by which it is put in communication with a steam pipe C. Steam is supplied through the hollow shaft into the several compartments of the wheel through perforations in the shaft. The introduction of the steam alone into the dash wheel is sufficient to improve greatly the ordinary bleaching, washing, and cleansing and "posting" effect of the wheel ; but with the farther introduction of acids, alkalis, soap, and other bleaching or preparing ingredients, the dash wheel is made directly available as an excellent bleaching apparatus. The various preparations are contained in cisterns placed above the level of the range of dash wheels, and a pipe from each cistern runs along the line of wheels, each pipe communicating with a branch pipe D leading to the hollow shaft B of the dash wheel, the pipe E immediately joining the hollow shaft being connected to it by a stuffing box joint. Each branch pipe D is fitted with a valve, in order that the quantity of each ingredient and the time during which it is admitted into the wheel may be easily regulated. The small quantity of water required in the process is also introduced through the same pipe E from one of the branch pipes D. The fluids have egress from the wheel by outlets F at or near the circumference, as shown in Fig. 2, the outlets being fitted with doors or valves by means of which they may be closed or opened at pleasure. The goods to be bleached are introduced into the wheel in the usual manner by doors G in the face or side.

The dash wheel shown in the engravings is intended to be driven by means of a small single independent steam engine, the rotary motion being first imparted to a pinion, in gear with an internally toothed wheel or rim H upon the back of the dash wheel. The smaller sized dash wheels are driven by bevil gearing from a shaft. The rate at which the wheels are driven depends upon their size ; a wheel 6 feet in diameter must make about 24 revolutions per minute, whilst 16 revolutions per minute are sufficient for a wheel 9 feet in diameter; in other words, the velocity at the circumference is in each case about 430 feet per minute. The steam is introduced into the wheels at a pressure of from 3 to 5 lbs. per square inch above the atmosphere, and an engine working up to 5 horse power will drive a 9 feet wheel.

The system of bleaching hitherto in use differs widely from the process at present under consideration; the former is confined exclusively to what may be termed the quiescent or inactive system, the goods operated upon merely undergoing the change of a removal from one steeping process to another, with little or no agitation beyond that due to the boiling action. In the new process the fabrics to be bleached are at once placed in the rotating wheel, the chemical agents are introduced into the wheel, and the steam is turned on. During the rotation of the wheel the goods are subjected to a motion which is continually effecting a series of changes in their position and greatly accelerates the cleansing action.

Various classes of goods may be thus treated, from the heaviest description of cotton or flax manufactures to the most fragile laces, without the slightest injury to the fabric. Perhaps what are termed sewed muslins or embroidered goods are the most difficult to bleach, from the almost indelible character of the ink, grease, and other extraneous matter, imbibed in the process of manufacturing, in connection with the delicate nature of the material. The writer as a manufacturer and bleacher of these goods has had ample opportunity of fully testing this invention, which he has exclusively adopted for the last eighteen months. One of the most extensive bleaching firms of this class of goods in Scotland, Messrs. Cochrane and Armour, of Neilston, have also discarded their old process and adopted the new one. By the old system sewed muslins take thirty days on an average before they are returned by the bleacher, whilst with the new process they can be regularly finished in three days; and besides this great saving of time, there is also a great advantage from the fact that as much as 50 per cent. less of chemicals, soap, fuel, and labour is required with the steam dash wheel. For linens this invention is invaluable, as it has been proved beyond doubt that the heavy linens and damasks made in the north of Scotland and Ireland can be bleached in one twelfth of the time and at considerably less expense by the dash wheel, whilst none of the large tracts of ground at present occupied for grass bleaching will in future be required for this purpose, but may be all taken up for agricultural uses. Calicoes are bleached by this process at Messrs. Ormerod and Co.'s works, near Manchester, in six hours; whereas by the old process the time required to bleach these goods is nearly as many days. The steam dash wheel may in fact be said to contain in itself a complete bleachwork.

The steam dash wheel is also of great advantage to paper makers, as an apparatus for removing the dirt and colour from the rags. Cotton waste after having been used by engineers has been cleansed and whitened and made fit for use again in less than four hours. As a washing apparatus for clothes, it has many advantages, as a single wheel will do the work of 200 washerwomen.

Mr. FOTHERGILL said he was much interested with the subject of the paper, and felt satisfied the invention would prove of very great value to the bleaching trade of Scotland and Lancashire from the remarkable expedition and economy of the process. It might also be made a great advantage to the public baths and wash-houses, in reducing the cost of washing. The application of the process to the cotton waste used for cleaning locomotive engines might, he thought, probably be made with advantage; the waste now cost the railway companies many thousand pounds annually, and a great saving might be effected if it could be economically cleaned for repeated use.

Mr. SCOTT RUSSELL thought the improved process that had been described was one of great interest and value, and might probably be extended to many useful purposes. He remarked that advantage would be likely to arise from the meetings of the Institution being held in various places, as many important applications might be suggested of improvements and inventions, in consequence of the meeting together of persons engaged in different local objects, who would not otherwise have the opportunity of communicating with one another.

A vote of thanks was proposed and passed to Mr. Wallace for his paper.

The following Paper, by Mr. William Gorman, of Glasgow, was then read :—

DESCRIPTION OF AN IMPROVED WATER METER.

To produce a machine capable of measuring water under pressure, and otherwise suitable for general use, it is necessary that certain conditions inseparable from this ponderable and practically non-elastic fluid should be complied with.

Accuracy in measurement is very properly the first object to be attained, and the machine must be accurate not only when newly made, but must be permanently so, in order to be trustworthy. The meter must also deliver the water undiminished in pressure as far as possible, whatever force is necessary to pass the water through the meter being lost in the pressure of the discharge. Thus with a head of water 50 feet high, if it takes a head of 25 feet to work the meter, the water delivered can be supplied only 25 feet high; and such a meter should be considered only half as efficient as one that delivers the water to the full height from which it is supplied.

It is also necessary that machines moved by water should work as smoothly and uniformly as possible, and that the current of water in the supply pipes should in no case be suddenly checked, since this is not only detrimental to the machine itself, but affects all the water works in the neighbourhood. It is farther desirable that a meter should be capable of passing as bulky matter as possible; for however carefully the water may be filtered, a great deal of debris collects from the interior of the pipes, and workmen sometimes allow rope yarn to get into the pipes in making a joint. Meters have been found stopped by pieces of lead which had been left in the pipes when undergoing repairs.

Another very desirable object is that the measuring apparatus of the meter should at all times be propelled by the water, and that no springs or weights should be depended upon for continuing the action, as the least derangement of the works impedes their action and the water is then allowed to pass without propelling the meter. When this takes place there is no chance of the meter starting again, as water will pass by the most free course; whereas when a meter is so constructed that no water can pass without acting on the machinery, the force of the water is always present, and no ordinary obstruction will prevent registration when water is being drawn off.

The meter that forms the subject of the present paper is thought by the writer to include most of the above requirements. It is shown in Figs. 1 and 2, Plate 86; Fig. 1 is a sectional plan inverted, and Fig. 2 a vertical section.

The meter consists of a casing A, containing a vane wheel B driven round by the water, which is admitted at the circumference of the wheel in a direction tangential to the circle described by the vanes, and drawn off from the centre. The openings for the supply of the water are regulated by self-acting loaded valves C, which contract the orifices when the flow is small, opening at all times only to an extent proportioned to the quantity of water passing through, thus preventing the stream from becoming too feeble on account of its small velocity to move the vane wheel.

The vane wheel B acts in the same manner as a light body, free to move, introduced into a pipe containing water. If the floating substance did not come into contact with the inside of the pipe, it would move just as fast and as far as the water in the pipe. The sectional area of the pipe being known, the quantity of water can be determined by the distance the floating substance has moved in the pipe. Similarly in the present case, the quantity of water passing through the meter is measured by the velocity of revolution of the vane wheel B, the sectional area of the inlet or outlet pipe being known.

The meter above described is accurate in measurement under all circumstances which occur in practice, and as the measuring chamber and apparatus are not subject to wear, its accuracy must be permanent. Whatever pressure of water is supplied can also be nearly obtained after the water has been measured. The meter works smoothly and uniformly, and moves with equal power through every part of its revolution, as there are no dead points; and the water is delivered in a smooth uninterrupted stream. All the working parts are free from each other, none of them requiring to be in contact. The vane wheel may be kept as free from the case as is desirable, since the measurement does not depend on the size of the wheel, but on the capacity of the measuring chamber and the velocity of revolution of the wheel.

This meter was first experimented on when the Gorbal's Gravitation Company offered a premium for a water meter to work under pressure; and although the machinery was very imperfect, the results obtained were amply sufficient to establish the accuracy of its action. The meter was tested under pressures ranging from upwards of 200 feet head to less than an inch, the flow of water being reduced to $\frac{1}{4}$

gallon per minute. The meter was correct at all important runs, and even when the smallest quantities were being drawn off the variation in measurement did not exceed 2½ per cent.

In the meter with which the experiments were made, the regulating valves were not properly placed in relation to the vane wheel, and consequently the registration was deficient when minute quantities of water were passing through the meter. This objection has been completely obviated in subsequent meters, and there is now no difficulty in regulating the flow of the water by means of the adjusting screws and weights of the regulating valves, so as to render the indications correct under all pressures.

With reference to durability it may be stated that these meters have been going regularly in Glasgow for upwards of four years; and they have never had to be returned except in one instance, where the case was too small, and consequently got choked with debris. Although the meter went for more than the time guaranteed, still as the case was too small it was exchanged.

It has been thought that the quick going wheel in this meter would wear the soonest; but on the contrary it has several times been found in practice that the teeth of the slow moving wheels have been stripped in consequence of the spindle which carries the indication through the meter case to the outside getting jammed, when the fast moving wheels which did the damage were not perceptibly worn.

Except in the cases referred to, the writer has had no personal experience of the practical working of these meters; they are all tested before being sent away, and he has never heard of any being found to vary in their indication or get worn out.

Mr. Gorman exhibited a specimen of the meter in operation, with a glass cover to the case so as to show the action of the meter in working.

Professor Rankine had lately tried some experiments on the meter that had been described, which were not quite completed, but the result so far was satisfactory. Two quantities of 100 gallons each had been passed through at the rate of 7 gallons per minute, and the meter was found to register in one instance 99 and in the other 99½ gallons, or from ½ to 1 per cent. in defect; and again 20 gallons had been tried at the average rate of only 2 gallons per minute, when the meter was found equally accurate. The water was measured in a ten gallon vessel, which would be more accurate than a one gallon measure for the experiments.

Mr. SIEMENS had paid much attention to water meters for a long time, in endeavouring to obtain a satisfactory construction. The great variety of meters might be all classed either as impact or reaction meters, measuring by the velocity of the current, or as diaphragm or piston meters, measuring by capacity. The meter that had been described in the paper belonged to the former class, which he considered the more accurate in principle. From his own observations he believed that piston meters were liable to pass even more water without registration than the other class, after having been in use for a length of time, as it was impossible to keep the valves all in such perfect order that they would prevent loss of water and still not impede the action of the meter by causing too much friction. He did not think the meter that had been described differed much in principle from others that had been tried and not found satisfactory. The only complete trial of a meter to test it thoroughly was to let it work for a considerable length of time where the water was impure; and under such circumstances he thought the present meter would be found to choke with calcareous deposit, which would obstruct the working. In his own experience he had had to remove all the wheel work and spindles from the action of the water, and place them in a separate chamber effectually protected from the water. The experiments should also be varied between the extremes of pressure and velocity of discharge, from a head of 300 feet down to a few inches pressure only, and from running full bore to the smallest stream such as was produced by the mere leakage of a cock. Many meters that were correct under ordinary circumstances were found to fail under the extreme cases to which they were liable to be exposed in actual work.

Professor RANKINE said that in the experiments he had tried, the velocity of discharge was varied as much as 10 to 1, by partially closing the cock, in order to test the accuracy of measurement, and it was found to be still correct; there had not been however any opportunity of trying the effect of variations of pressure.

Mr. GORMAN observed that all meters which measured by the velocity of a current would be found to indicate in excess at high velocities, or lose at small runs. He had applied the regulating valves in the present meter to obviate this objection, by diminishing the area of the flow and thereby increasing its force when discharging very slowly, and he considered they answered the purpose effectually. With regard to placing the wheelwork entirely out of the water, he had not experienced any difficulty in Glasgow, where the water was not so clean as in many other places, and he did not think any objection was to be apprehended from that cause. The only accidents that had occurred were from the spindle which passed outside the meter getting retarded, when it was invariably found that although the teeth were stripped off the slow moving wheels the teeth of the quick moving wheels were not perceptibly worn, pointing to the great advantage of doing work at high speeds.

Mr. Ramsbottom enquired what was the slowest rate of discharge that had been measured with the meter.

Mr. Gorman replied that the smallest discharge experimented upon was ½ pint per minute, and the error in measurement was then only ½ gallon in 100 gallons, or ½ per cent. There might possibly be an error in testing by filling the 10 gallon measure, but this could be only very small in amount.

Mr. Fothergill suggested that the wheelwork might be separated by a shaft or spindle passing into a separate chamber, so as to prevent all risk of corrosion or incrustation.

Mr. Gorman said the wheelwork had been placed outside the meter at first, in a separate chamber, but was now put inside, because that construction was found more convenient, and he did not apprehend any serious objection to it in practice.

Mr. Scott observed that the cost of meters was an important question, as there was no difficulty now in obtaining meters for measuring a large supply with sufficient accuracy; but the difficulty was to bring meters into use for a small supply, where the meters became too expensive in proportion to the quantity of water consumed. Gas meters seldom cost so much as the gas passed through them in one year; but the cost of a water meter was five times that of the annual supply of water, which was more than could be afforded ordinarily.

Mr. Neilson agreed that a great element in meters was a low cost, and there was no doubt that if the water were only 5*s.* or 10*s.* rental per annum a price of £2 or £3 could not be paid for a meter to measure that quantity of water, as it would amount to 6 or 8 years' rental of the water.

Mr. Siemens observed that there had not yet been any demand for meters for small households, which would probably be better charged as at present by an average amount according to the size of house; for the total quantity of water used in such cases was but a small proportion of the whole, and it did not seem a good policy to check the use of water in the lower class of houses. The smallest meters at present made cost about 45*s.*, and were of a size suitable for large householders paying about the same amount of water rent per annum.

A vote of thanks was proposed and passed to Mr. Gorman for his paper and the working model of the meter that was exhibited.

The CHAIRMAN moved a special vote of thanks to the Local Committee for their great exertions and the excellent arrangements made by them for the meeting of the Institution, and the very spirited and hospitable reception they had given to the Members. They had received many valuable and interesting communications, and the meeting had proved entirely successful; and he looked forward with great pleasure to meeting again in the same place.

Professor RANKINE, as Chairman of the Local Committee, acknowledged the vote of thanks, and said that the announcement of the intention of the Institution to visit Glasgow again was a source of great gratification to them, and that they felt that the success of their endeavours was the best reward they could receive.

He then moved a vote of thanks to the President, which was passed.

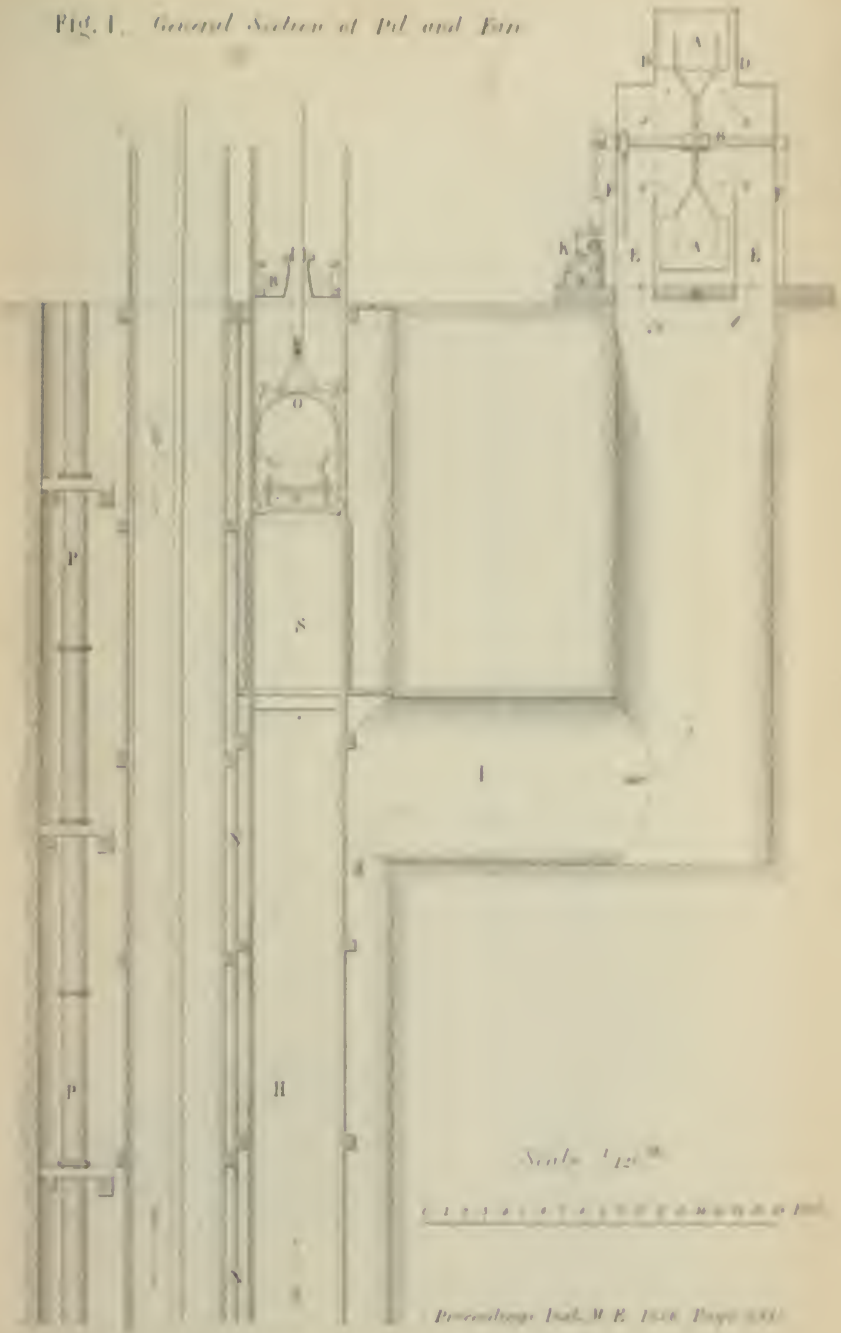
The Meeting then terminated; and after the meeting, Boucherie's Mode of Preserving Timber was exhibited by Mr. John Reid, Jun., in operation in adjoining premises.

A large number of machines and models were also exhibited after each of the Meetings.

In the evening a large party of the Members and their friends dined together in celebration of the first Meeting of the Institution in Glasgow.

On the following day the Members were invited by the Local Committee and their friends to a day's excursion down the Clyde and to the adjacent Lochs in a special steamer.

Fig. 1. *General Section of Pit and Fan*



Scale 1/12th

VENTILATING FAN. Plate 89

Fig. 2. Section of Pit showing Cage ascending

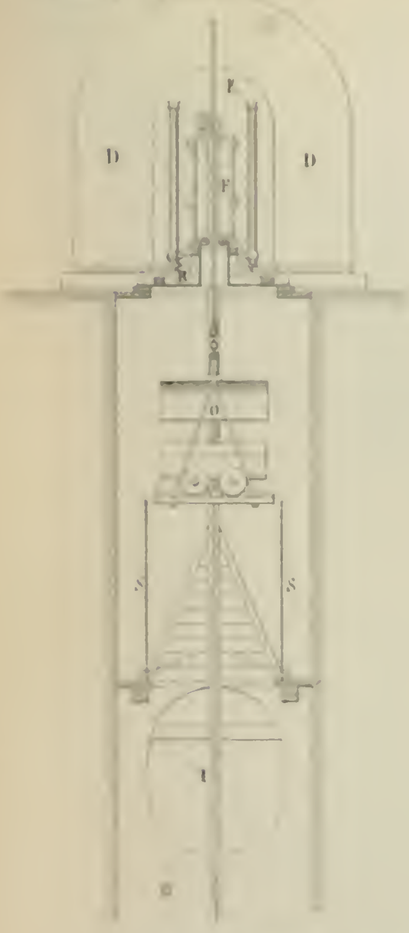


Fig. 3. Section of Pit showing Cage at top

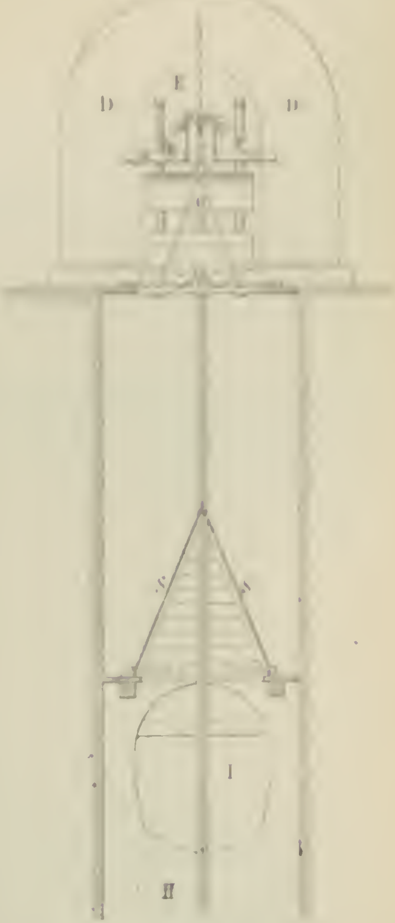
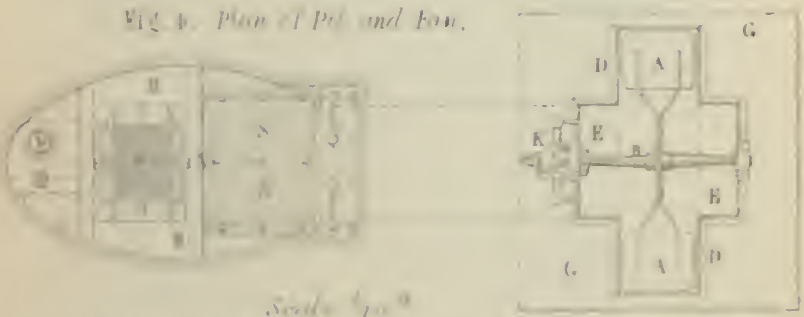


Fig. 4. Plan of Pit and Fan.



Scale $\frac{1}{120}$th

10 9 8 7 6 5 4 3 2 1 0 10 20 Feet

Proceedings Inst. M.E. 1858. Page [illegible]

VENTILATING FAN.

Fig. 5 Side Elevation of Fan and Engine enlarged.

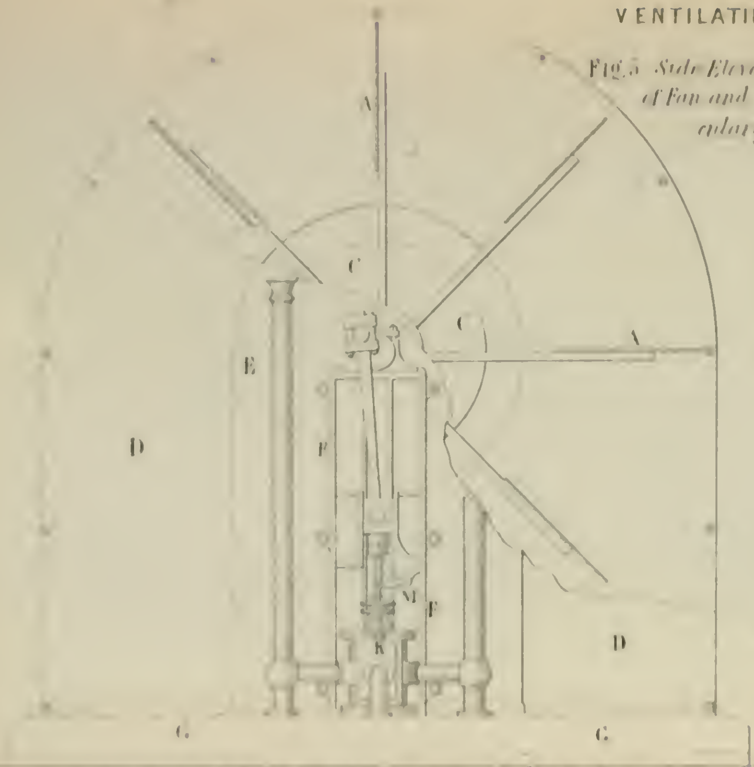
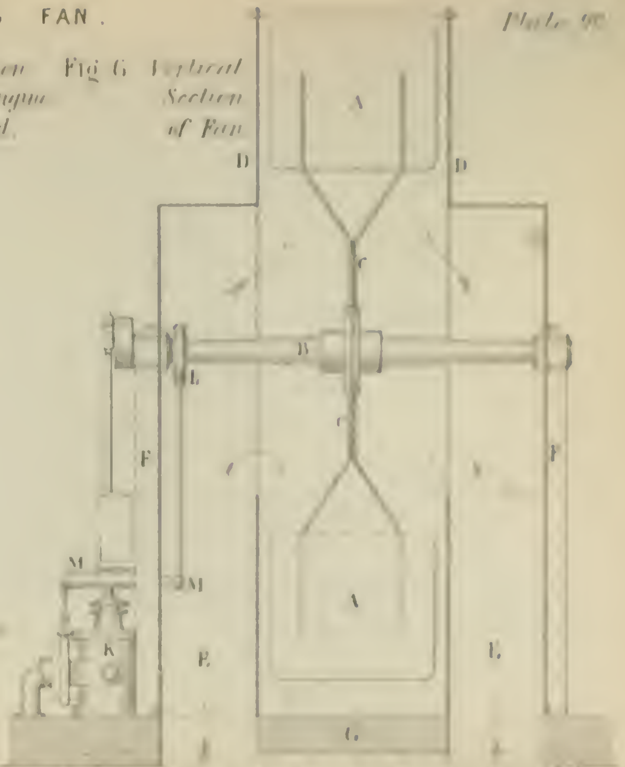


Fig. 6 Vertical Section of Fan

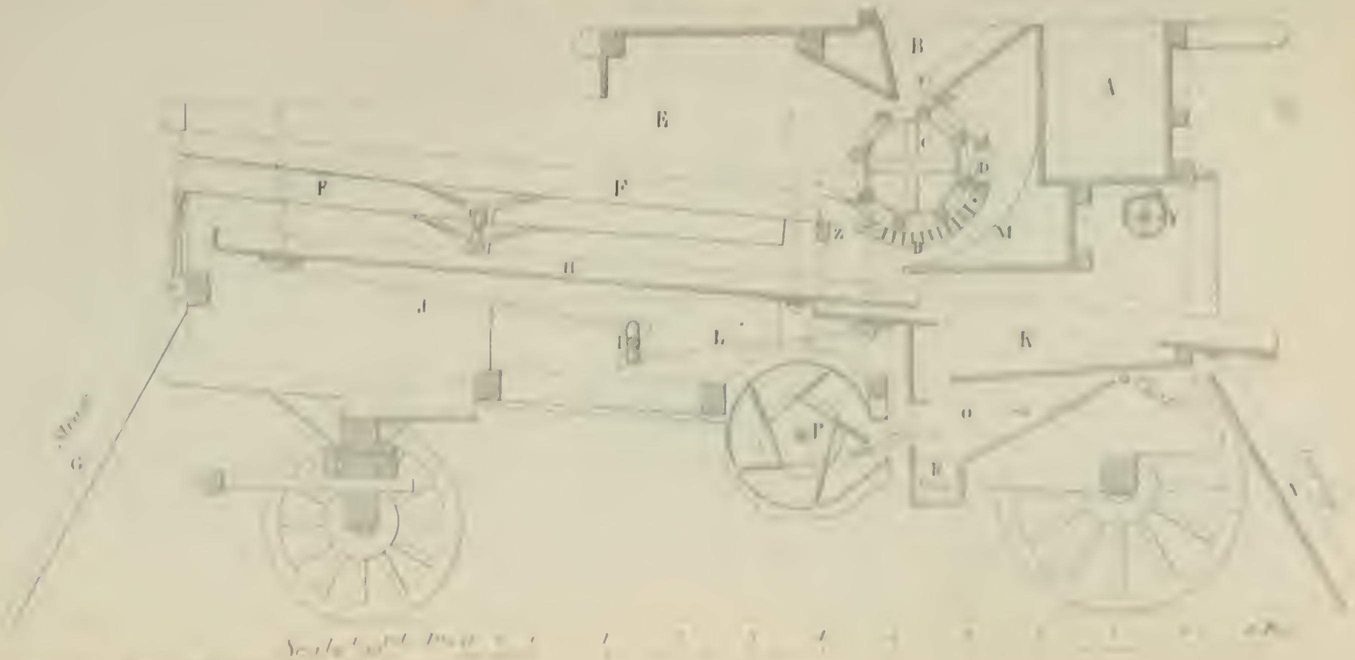


Scale 1/48th Feet

BARN MACHINERY.

PORTABLE STEAM THRESHING MACHINE

Fig 1 Longitudinal Section.



Scale [illegible]

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BARN MACHINERY

CORN DRESSING MACHINE AND ELEVATOR.

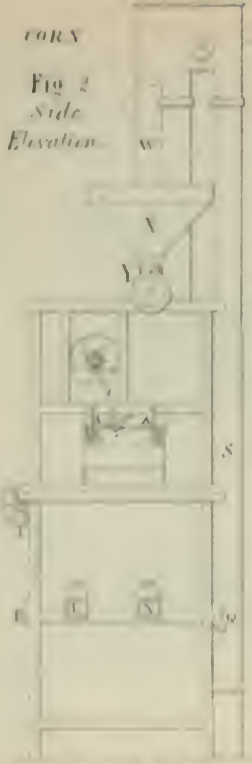


Fig 2
Side
Elevation.

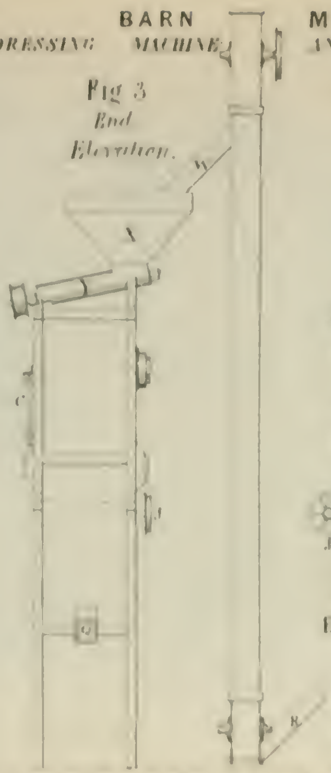


Fig 3
End
Elevation.

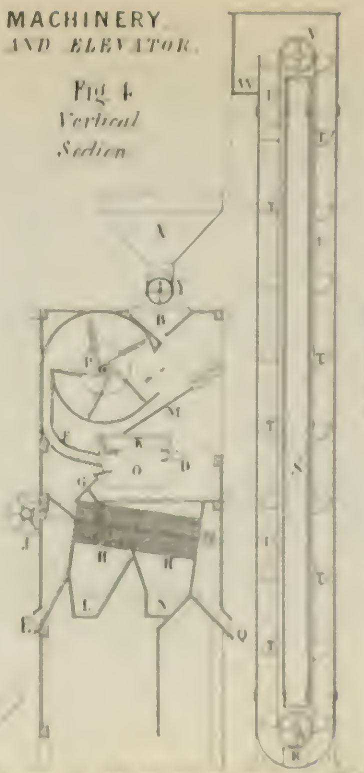


Fig 4
Vertical
Section.

SEPARATORS

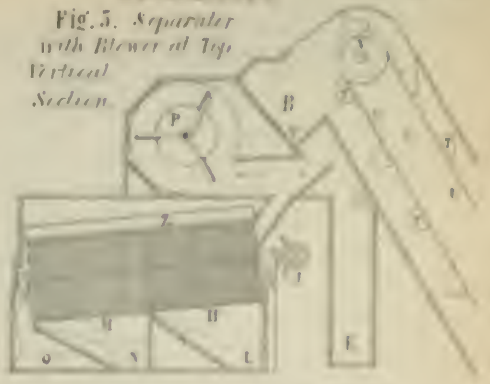


Fig. 5. Separator
with Blower at Top.
Vertical
Section.

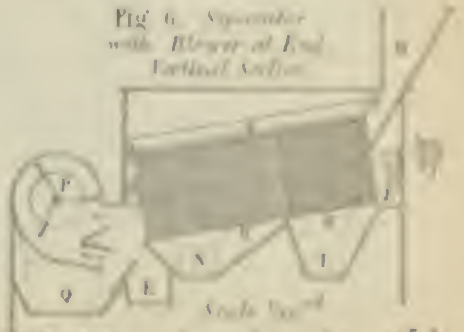


Fig 6. Separator
with Blower at End.
Vertical Section.

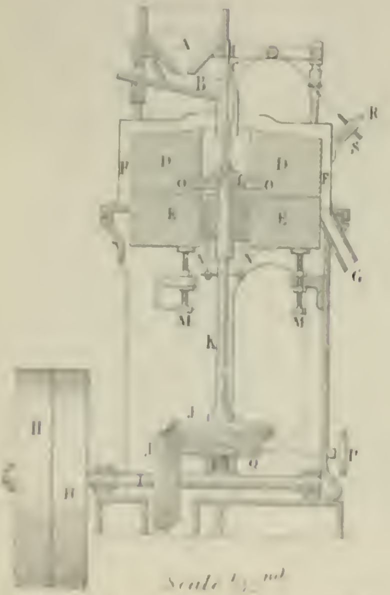
Scale [illegible]

Scale [illegible]

BARN MACHINERY.

PORTABLE CORN MILL.

Fig. 7. Vertical Section.



Scale 1/32nd

Ins 12 6 0 1 2 3 Feet

THRESHING DRUMS.

Fig. 8.

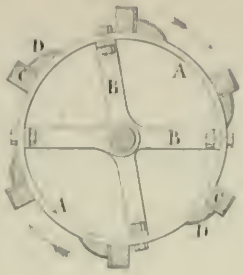


Fig. 9.

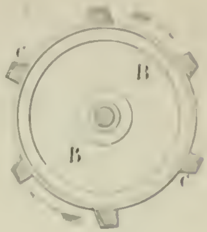


Fig. 10.

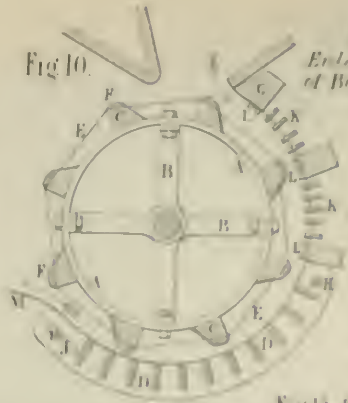


Fig. 11
Enlarged View of Beater Plates.

Scale 1/4

Fig. 12.

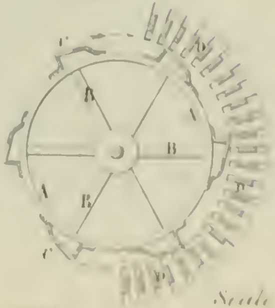


Fig. 13.

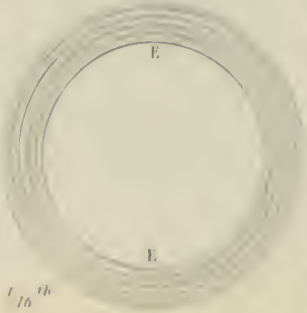


Fig. 14.

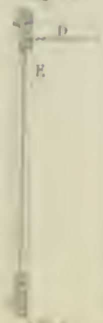
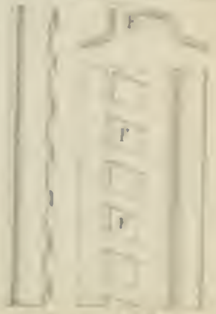


Fig. 15. Enlarged View of Beater Plates.



Scale 1/4th

Scale 1/16th

Ins 12 6 0 1 2 3 Feet

BARN MACHINERY

Plate 94

RAIL STRAW SHAKER

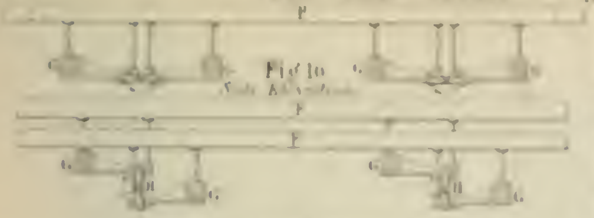
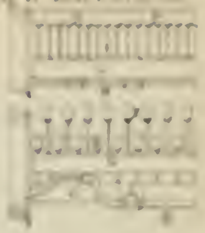


Fig 17 End Elevation



BOX STRAW SHAKER.

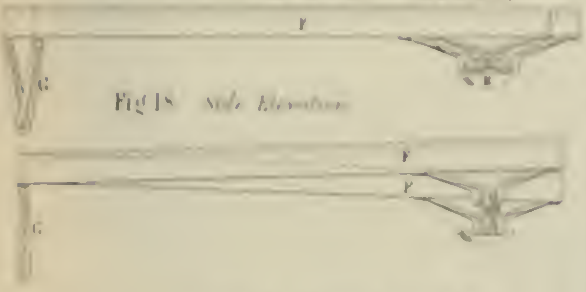
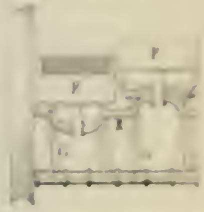


Fig 18 Side Elevation

Fig 19
End Elevation



CROSS STRAW SHAKER.

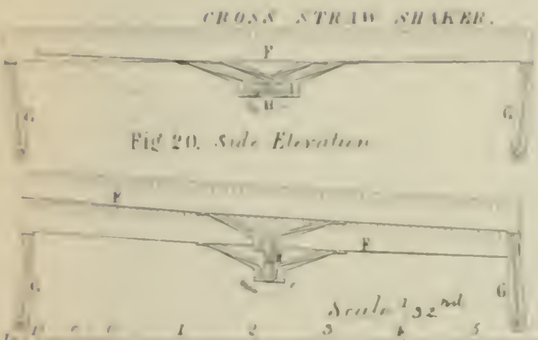
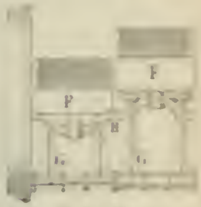


Fig 20. Side Elevation

Fig 21
End Elevation



BARLEY HORNER.

Fig. 22. Side Elevation

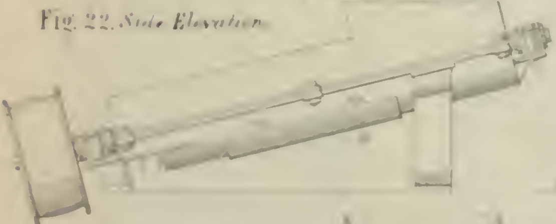


Fig 24. End Elevation

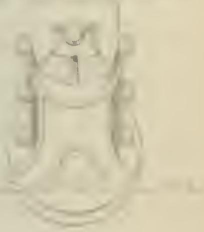


Fig 23 Longitudinal Section

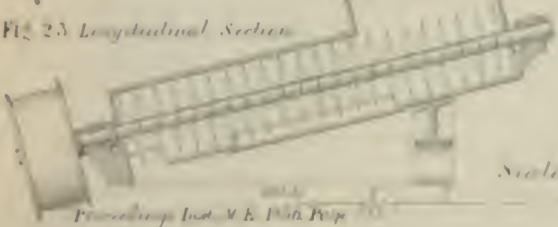
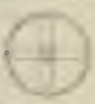


Fig 25
Transverse Section

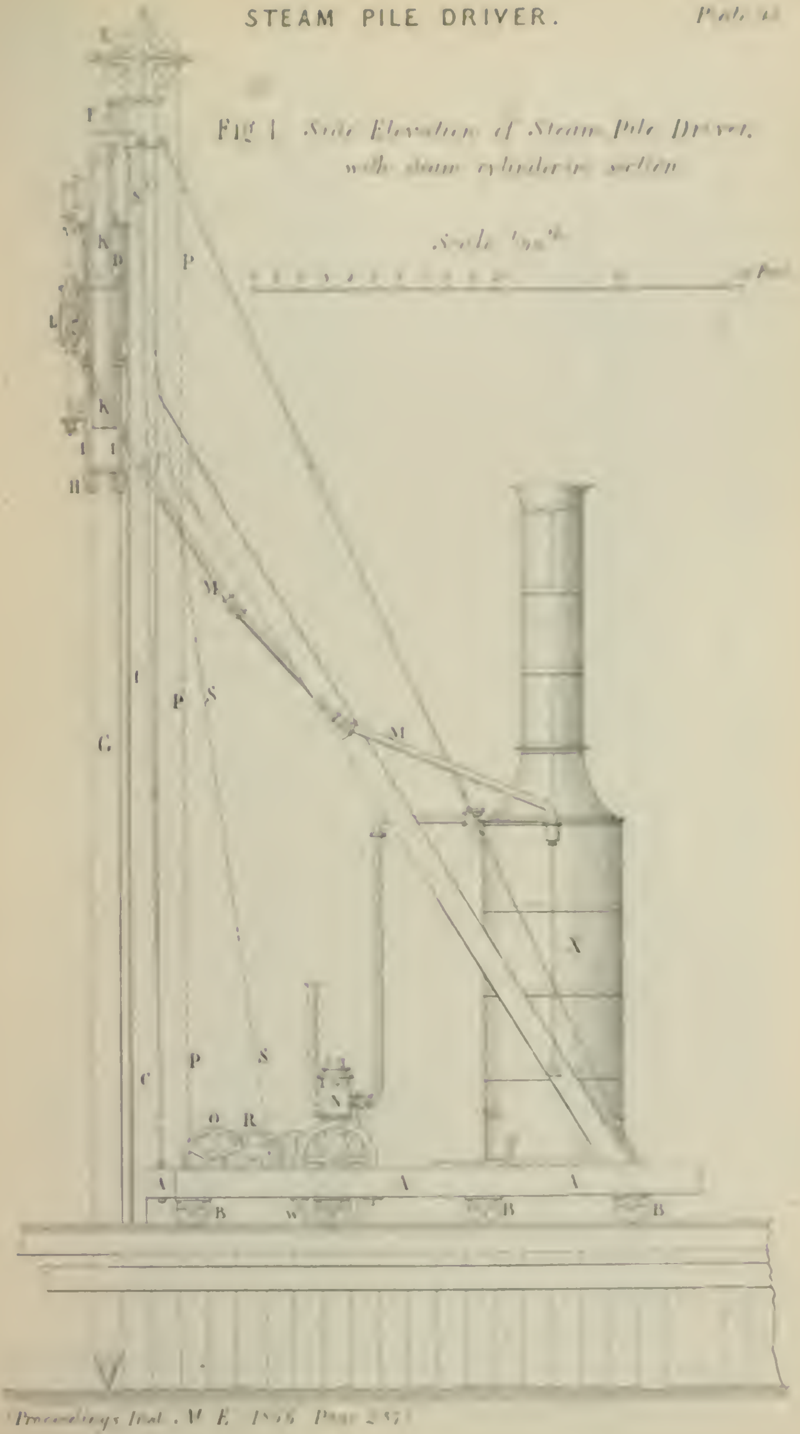


Proceedings Inst. M. E. 1856. Page

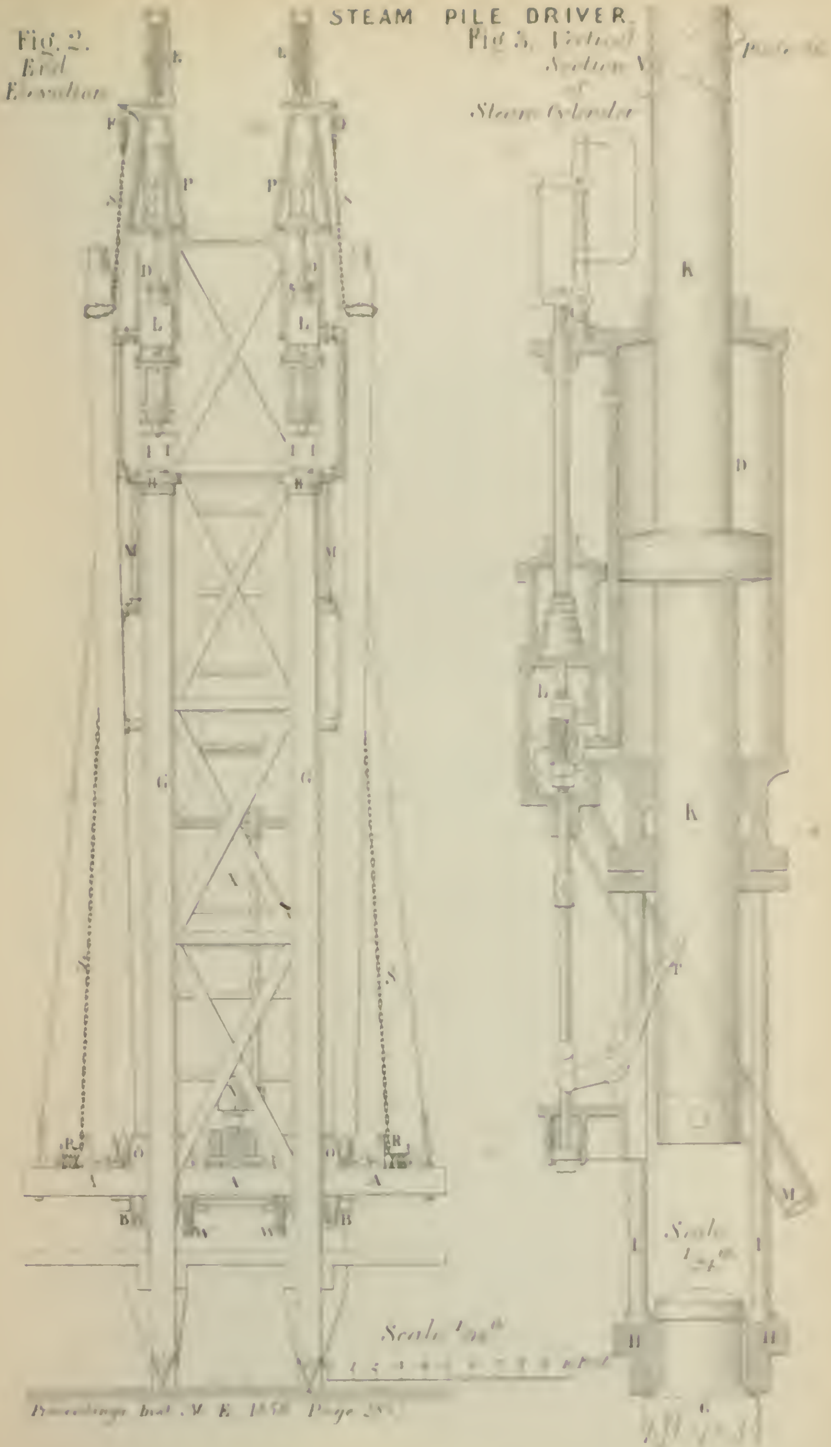
STEAM PILE DRIVER.

Fig 1. Side Elevation of Steam Pile Driver, with steam cylinder in section

Scale 1/48th



STEAM PILE DRIVER.



Proceedings Inst. M. E. 1858. Page [illegible]

PROCEEDINGS.

November 5, 1856.

The General Meeting of the Members was held at the house of the Institution, Newhall Street, Birmingham, on Wednesday, 5th November, 1856; Sampson Lloyd, Esq., in the Chair.

The Secretary read the Minutes of the last Meeting, held in Glasgow, which were confirmed.

The Chairman announced that according to the rules of the Institution, the President, Vice-Presidents, and five of the Council in rotation would go out of office in the ensuing year; and that at the present Meeting the Council and Officers were to be nominated for the election at the next Annual Meeting.

The following list of Members was adopted by the Meeting for the election at the Annual Meeting.

PRESIDENT.

Joseph Whitworth, Manchester.

VICE-PRESIDENTS.

(Six of the number to be elected.)

Samuel H. Blackwell, Dudley.
William Fairbairn, Manchester.
James Fenton, Bradford.
Benjamin Fothergill, Manchester.
Sampson Lloyd, Wednesbury.
Henry Maudslay, London.
James E. McConnell, Wolverton.
John Ramsbottom, Manchester.

COUNCIL.

(Five of the number to be elected.)

ALEXANDER ALLAN, Perth.
EDWARD A. COWPER, London.
WILLIAM G. CRAIG, Manchester.
JAMES FENTON, Bradford.
JOHN FERNIE, Derby.
WILLIAM MATHEWS, Dudley.
C. WILLIAM SIEMENS, London.
HENRY WOODHOUSE, Stafford.

The CHAIRMAN announced that the Ballot Lists had been opened by the Committee appointed for that purpose, and the following New Members were duly elected :—

MEMBERS.

JOHN ANDERSON, . . .	Woolwich.
ISAAC BLACKBURN, . . .	Long Eaton.
ALEXANDER CHAPLIN, . .	Glasgow.
EDGAR GILKES, ...	Middlesboro'.
THOMAS HUNT, . . .	Crewe.
JABEZ JAMES, ...	London.
FREDERICK LEVICK, . .	Blaina.
JOHN MACKAY, ...	Drogheda.
ROBERT NAPIER, . . .	Glasgow.
FRANCIS PRESTON, . . .	Manchester.
CHARLES REEVES, . . .	Birmingham.
JOSIAH RICHARDS, . . .	Ebbw Vale.

HONORARY MEMBER.

JOHN MARSHALL, . . .	Bradford.

The following Paper, by Mr. Ebenezer Rogers, of Abercarn, was then read :—

DESCRIPTION OF THE VENTILATING FAN AT THE ABERCARN COLLIERIES.

The mode of ventilation that is still generally used in the collieries of this country is the old furnace ventilation, where the required current of air through the mine is maintained by the rarefaction of the column of air in the ascending shaft, by means of a large fire kept constantly burning at the bottom of the shaft. In Belgium and France, on the contrary, this plan is almost superseded by the use of machinery to maintain the current of air, as the furnace ventilation, although possessing the important advantages of great simplicity and freedom from liability to derangement from disturbing causes, has some serious objections and deficiencies, and in some cases becomes so imperfect a provision for ventilation as to render a better system highly desirable and even necessary.

The author of the present paper, having occasion to ventilate the workings in some extensive and very fiery coal seams recently won at Abercarn in South Wales, under circumstances where the furnace ventilation could not be applied, after carefully collecting every accessible information as to the ventilating machines used in Great Britain and on the Continent, came to the conclusion that a plan of machine proposed for the purpose some years since by Mr. James Nasmyth would be the most suitable and effective. After consultation with Mr. Nasmyth, it was resolved to test the principle and plan by actual practice; and the ventilating fan described in the present paper was made at Patricroft by Mr. Nasmyth, and is erected and now working at the Abercarn Collieries.

The general arrangements of the top of the shaft and the ventilating fan are shown in Figs. 1 to 4, Plates 88 and 89; Figs. 1, 2, and 3 are vertical sections, showing the air valves at the mouth of the pit, and the passage connecting the fan with the pit; Fig. 4 is a sectional plan of the pit and fan.

Fig. 5, Plate 90, is a side elevation of the fan and engine, to a larger scale; and Fig. 6 a vertical section of the fan.

The fan AA, Fig. 6, is 13½ feet diameter, with 8 vanes, each 3 feet 6 inches wide and 3 feet long. It is fixed on a horizontal shaft B, 8 feet

7 inches in length from centre to centre of the bearings, which are 9 inches long by $4\frac{1}{2}$ inches diameter. The vanes are of thin plate iron, and carried by forked wrought iron arms secured to a centre disc C fixed upon the shaft B. The fan works within a casing DD consisting of two fixed sides of thin wrought plate, entirely open round the circumference and connected together by stay rods; the sides are 3 inches clear from the edges of the vanes, and have a circular opening 6 feet diameter in the centre of each, from which rectangular wrought iron trunks EE are carried down for the entrance of the air, the bearings for the fan shaft B being fixed in the outer sides of these trunks, which are strengthened for the purpose by vertical cast iron standards F bolted to them and resting upon the bottom foundation stone G.

The two air trunks EE join together below the fan, as shown in Fig. 1, and communicate with the pit H by means of a horizontal tunnel I, which enters the pit at 21 feet depth from the top.

The fan is driven by a small direct-acting non-condensing engine K, which is fixed upon the face of one of the vertical cast iron standards F, and is connected to a crank on the end of the fan shaft B. The steam cylinder is 12 inches diameter and 12 inches stroke, and is worked by steam from the boilers of the winding engine of the pit, at a pressure of about 13 lbs. per square inch. The eccentric L for the slide valve is placed just inside the air trunk E, and works the valve through a short weigh shaft M with a lever on the outside.

The pit H, Fig. 4, is of an oval form, 10 feet by 18 feet, and divided near the centre by a timber brattice N, the one side forming the upcast shaft and the other the downcast. Both of these are used for winding, and the cages O, in which the trucks, &c., are brought up, work between guides fixed to the timbering of the pit. The pumps P are placed in the downcast shaft.

In order to allow of the upcast shaft being used for winding, the top is closed by an air valve R, which is formed by simply boarding up the underside of the ordinary guard upon the mouth of the shaft, leaving only the hole in the centre through which the chain works. This air valve R is carried up by the cage O on arriving at the top of the shaft, as in Fig. 3, and then drops down again flat upon the opening when the cage is again lowered, as in Fig. 2. During the time that the valve is lifted, its place is occupied by the close bottom of the cage O, which nearly fills the rectangular opening left at the top of the shaft. By this simple means it is found practically that a complete provision is made for keeping the top of the upcast shaft closed, and maintaining a uniform current of air up the shaft; for the leakage of air downwards through the top whilst the cage is in the act of opening or closing the air valve, and through the small area that always remains open, is found to be quite immaterial, and the surplus ventilating power of the fan is amply sufficient to provide against it.

In the original construction a more perfect air valve was supposed to be requisite, and was provided by the inclined flaps SS, which are fixed just above the horizontal tunnel I. These are fitted closely together, leaving only a small opening in the centre for the chain to pass through, and were intended to be opened by the ascending cage coming in contact with them, closing again directly by means of balance weights before the air valve R at the top of the shaft was opened, so as to preserve a thorough closing of the top of the shaft. The flaps were to be opened again by a lever from the top to allow the cage to descend. However, it was found on trial that the valve R at the top was amply sufficient; and consequently, although the other valves S were also provided, they have never been put into use.

The total depth of the pit is nearly 300 yards, and at a depth of 120 yards a split of air is taken off, and coursed through workings from which coal and fire clay are got; the larger portion of the air descends to the bottom of the pit, and is there split into many courses, to work two separate seams of coal and a vein of ironstone. The total length of road laid with plates or rails in the workings is about 7 miles, and the working faces amount to nearly double that distance. The longest distance that is traversed by any single course or split of air in passing from the downcast to the upcast shaft is nearly 2 miles. The quantity of materials raised from the pit is about 500 tons daily.

The speed at which the ventilating fan is usually worked is about 60 revolutions per minute, giving a velocity at the circumference of the fan of 2545 feet per minute; 45000 cubic feet of air per minute are then drawn through the mine, nearly one third of which ventilates the upper workings, and the rest passes through the lower workings.

Table I (appended) gives the results of a series of experiments made with this ventilating fan under the direction of the author by Mr. R. S. Roper, showing that the quantity of air delivered at the velocities of 60 and 80 revolutions of the fan per minute is 45000 and 56000 cubic feet per minute, with a velocity of current of 782 and 1037 lineal feet per minute respectively, or about 9 and 12 miles per hour; and the degree of vacuum or exhaustion in the upcast shaft is ·5 and ·9 inch of water respectively.

In these experiments the mode adopted for ascertaining the velocity of the air currents was by calculation from the difference of pressure, as observed by means of a carefully constructed vacuum gauge, the result being checked by the anemometer and by the time of passage of the smoke of powder fired at fixed distances by means of wires from a voltaic battery at the top of the shaft.

The working velocity of the fan is readily and instantly regulated by means of a throttle valve in the steam pipe of the engine, which is under the control of the man in charge of the working of the pit, and is adjusted according to the requirements of the ventilation arising from changes in the atmospheric pressure and in the quantity of gas in the workings. It has been found that a velocity of about 50 to 60 revolutions per minute gives the best amount of ventilation, and that beyond 80 revolutions the current of air is too strong to allow of the lamps being kept alight in the workings.

This ventilating fan has been now in constant work for two years, night and day, without once stopping for repairs of any kind, and is in as good working order as when first started; there appears to be nothing to get out of order about the machine on account of the simplicity of its construction, and no reason to anticipate any failure. The engine is made very simple in construction, with large and durable wearing surfaces, and the steam cylinder is fitted with a solid metal piston to prevent any occasion for stopping to adjust the packing. The whole cost of the steam power for working the fan is so insignificant that a little leakage of steam is quite immaterial. The complete arrangement would be to have a second duplicate fan fixed complete, and ready to be set to work at any moment if the first was stopped, or to work in conjunction with it on any emergency requiring greatly increased ventilation; though from the experience of the present fan it has not appeared requisite to take any such precaution.

In case of putting up another fan for a similar purpose, the author would adopt one of still larger diameter, probably 21 feet diameter, and running at a slow speed, which he considers would be preferable and still more economical in power. The construction of the casing of the fan he would propose to make of a simpler and less expensive description, using only thin brick walls for the sides and the air trunks. The whole expense would then be very inconsiderable, even for a complete pair of the ventilating fans.

The ventilating fan has a very important advantage over the furnace ventilation, in the power it affords of suddenly increasing the current of air to a great extent in any emergency, whilst with the furnace any increase is very slow in action and limited in extent, and cannot be effected from the surface of the ground.

Another advantage is the coolness and freshness of the upcast shaft, which can be used for the passage of the men as freely as the downcast shaft, being free from the heat and smoke of the furnace ventilation.

There is also no risk of explosion from the access of gas to the furnace fire; and in the first opening of a fiery seam, as in the present case at Abercarn, a furnace could not have been safely lighted until after a long delay for drainage of the gas, owing to the sudden and extensive liberation of gas, and even then it would have been attended with considerable difficulty and danger; but with the help of the fan all delay and danger was avoided, and the workings commenced immediately on reaching the seam.

A bratticed shaft was the only plan practicable in the present case, on account of the great difficulty of sinking deep through the rock, which was of remarkable hardness; and in such cases the furnace ventilation is very objectionable on account of the constant leakage caused by the drying of the timber of the brattice from the effects of the heat of the fire, and the corroding action of the sulphurous vapours of the furnace smoke.

By employing the suction in place of the blowing action, and having a fan of large diameter, great exhausting power is obtained without requiring a high velocity of rotation; the circumference of the fan case being left open allows the air to be expelled all round with perfect freedom, and the central diaphragm plate on the fan spindle prevents the opposite currents of air entering at each side from impeding each other. The simple manner of driving, by an engine acting direct by a crank on the fan spindle, saves the necessity for intermediate gearing; and by having the fan on the surface of the ground exposed to sight, its action and rate can be seen at all times to be effective, whilst it is safe from the chance of any damage arising from an explosion, were one to occur.

In the pit at Abercarn the quantity of gas is so serious that safety lamps are now used exclusively throughout the workings, and not a single naked light is allowed, except at the two stations near the shaft where the safety lamps are lighted and locked up. Several very slight explosions have occurred, but not any at all serious in their consequences, except one, which may be mentioned as a useful example of the great practical value of a means of suddenly producing a greatly increased current of ventilation, in preventing loss of life from the result of explosion. In this instance, which occurred about October, 1855, one of the men took a naked candle into a stall in which fire damp had accumulated in the lower workings, at about 150 yards distance from the shaft. An explosion ensued, which was heard by the author, who was at the top of the shaft at the time; and he instantly turned the steam full on to the engine of the fan, which immediately increased the speed of the fan to nearly double its rate, and caused such a sudden increase in the velocity of the current of ventilation, that the after damp resulting from the explosion was carried past the men in the workings so quickly that they escaped all serious injury, so momentary was their exposure to its effects. But if the ordinary velocity of current only had been maintained, some of these men could not have escaped with their lives. The man who caused the explosion was severely burnt, but recovered from the injury.

Almost immediately after turning on the steam to the fan, a shower of black particles was thrown out of the fan, which would be the result of the explosion, being the fine particles of carbon, liberated as light flaky soot from the decomposition of the carburetted hydrogen by the explosion. This is commonly but incorrectly called "coal dust," and is always the result of an explosion; and in the author's opinion this is the cause of the fatal effect of the after damp, from the accumulation of the minute solid particles upon the lungs, and not the exposure to the carbonic acid and nitrogen resulting from the combustion of the gas and air. This opinion is confirmed by the result of examination of the lungs of men killed by mine explosions, which are found to be loaded with these black solid particles. It has been observed frequently that men can live for some time in the after damp following a mine explosion, if they take the precaution to cover their mouths and nostrils completely with a handkerchief, so as to sift the air they breathe and prevent these floating particles of carbon from entering the lungs; and this precaution is enjoined in the rules of several mines, to prevent breathing the "coal dust" as it is termed. The author has known a case, where a miner, named John Hall, now living at Abercarn, got through a distance of half a mile filled with the after damp by taking this precaution, and escaped with safety to the shaft.

One of the most explosive mixtures of gases that can be produced in a coal mine is in the proportion of 5 volumes of carburetted hydrogen and 40 volumes of atmospheric air. When this mixture is exploded the results are 2 volumes of vapour of carbon, 3 volumes of carbonic acid gas, 10 volumes of vapour of water, and 32 volumes of nitrogen gas. After the explosion the carbon assumes the form of light flaky soot, which is very finely distributed throughout the air. Table II. illustrates the manner in which the writer believes that the decomposition and combinations accompanying the explosion take place.

A similar ventilating fan to that above described has been since erected by Mr. Nasmyth at Skiar Spring Colliery, near Elsecar, which is working with complete success; it is of rather larger size than the one at Abercarn, being 15 feet diameter and 4 feet 3 inches wide in the vanes, and is worked at 80 revolutions per minute by the steam from a pumping engine boiler at 15 lbs per square inch. The result is a thoroughly efficient ventilation of the workings, completely under control at the surface of the ground, and maintained at an expenditure of fuel extremely small as compared with that required for the ordinary furnace ventilation.

TABLE I.

Synopsis of Experiments on Fan Ventilation.

	Height of Barometer.		Temperature by Fahrenheit's Thermometer.				Revolutions of Fan per minute.	Water Gauge.	Velocity of Air in feet per minute.	Cubic feet of Air per minute.	Steam Gauge on Fan.	Theoretical Consumption of Coal per hour.
	At the Surface.	At the Bottom.	Top of Down-cast.	Bottom of Down-cast.	Bottom of Upcast.	10 yards from top of Upcast.						
	ins.	ins.	degs.	degs.	degs.	degs.	revs.	ins.	ft. p. min.	c. ft. p. min.	lbs.	lbs.
Mean of twelve experiments Natural Ventilation	29·61	30·60	41·10	51·73	55·56	48·00	...	·15	446·0	24325	...	...
Mean of four experiments Fan Ventilation	29·85	30·85	38·10	50·10	53·93	47·30	60	·50	781·8	45187	13·0	17·4
Mean of five experiments Fan Ventilation	29·65	30·61	41·40	50·70	55·10	48·70	80	·90	1037·0	56555	19·3	23·2

TABLE II.

Table illustrating a Mine Explosion.

BEFORE EXPLOSION.		AFTER EXPLOSION.			
5 vols. of Carburetted Hydrogen. 5 CH_2	40 vols. of Atmospheric Air. 8 O + 32 N	2 vols. of Vapour of Carbon. 2 C	3 vols. of Carbonic Acid Gas. 3 CO_2	10 vols. of Vapour of Water. 10 HO	32 vols. of Nitrogen Gas. 32 N
C 1 vol.		C 1 vol.			
C 1 vol.		C 1 vol.			
C 1 vol.	O ½ vol. O ½ vol.		CO_2 1 vol.		
C 1 vol.	O ½ vol. O ½ vol.		CO_2 1 vol.		
C 1 vol.	O ½ vol. O ½ vol.		CO_2 1 vol.		
H 1 vol.	O ½ vol.			HO 1 vol.	
H 1 vol.	O ½ vol.			HO 1 vol.	
H 1 vol.	O ½ vol.			HO 1 vol.	
H 1 vol.	O ½ vol.			HO 1 vol.	
H 1 vol.	O ½ vol.			HO 1 vol.	
H 1 vol.	O ½ vol.			HO 1 vol.	
H 1 vol.	O ½ vol.			HO 1 vol.	
H 1 vol.	O ½ vol.			HO 1 vol.	
H 1 vol.	O ½ vol.			HO 1 vol.	
H 1 vol.	O ½ vol.			HO 1 vol.	
	N 32 vols.				N 32 vols.

The chemical equivalent of oxygen by volume, or the combining volume of oxygen, being a half-vol., the 8 vols. of oxygen which are in mechanical mixture in the air before explosion represent the 16 equivalents or 16 half-vols. which are in chemical combination with the carbon and hydrogen after explosion.

The Chairman thought a more interesting and important paper could not have been brought before the Institution, for every one acquainted with the working of collieries must be aware of the great value of thoroughly efficient ventilation, and the danger and serious risk of life attending any imperfection in the system. Only a few months previously an explosion had occurred in Wales, by which more than a hundred persons had been killed in one pit, showing the necessity of adopting some efficient system of ventilation, that would not be liable to derangement from accidental causes; and the method now described was certainly a very simple and mechanical way of accomplishing this object. Several attempts at mechanical ventilation had been made previously, but did not appear to have met with much success in actual adoption: mechanical means had been tried, he believed, more in Wales than elsewhere, because the coal in that district contained such a large proportion of explosive compounds. He enquired what were the essential points of difference in the previous methods from the one now described.

Mr. Rogers replied that there was nothing new in the principle of ventilation by purely mechanical means; the same principle had been in use centuries ago on the continent, although of comparatively recent introduction into this country. The old German miners had used an inverted tub, placed in water, and worked up and down by a lever, with an air valve at the top opening inwards, the fresh air being alternately drawn into the tub and expelled along an air main conducting it into the workings. This rude contrivance had been recently improved and the plan carried out on a large scale in Struve's ventilator, in which the inverted air vessels were like large gasometers; but the apparatus was expensive and proved troublesome in working. Rotary ventilators, acting on the principle of the screw, had been tried in some cases; and the fan had also been applied, but without success, in consequence, he considered, of a want of mechanical knowledge on the part of those who had sought to adopt this method of ventilation. The need of sound mechanical applications in carrying out improvements of this nature formed his principal reason for bringing the present subject before the Institution, with the view of drawing attention to its importance.

The fan at Abercarn had proved completely successful, and he was not aware that any really effective machine had been produced previously; but the subsequent one at Skiar Spring Colliery was still better, and experience would no doubt lead to yet farther improvements, particularly in a still farther increase of the diameter of the fan. In some of the early attempts the air was forced down the pit by a blowing fan, which was beginning at the wrong end of the process; and another mistake that had been made was that the area of the branch air passages was too small at the point of taking off the air, causing a serious waste of power and a check to the current in passing the contracted parts. In Mr Nasmyth's fan the simple direct-acting engine was an important feature, together with the compact arrangement of the machinery, requiring no foundation but the fan case itself, and giving no trouble in keeping it in repair. The engine was capable of driving the fan at 100 to 120 revolutions per minute if requisite in an emergency, but the ordinary speed was 50 or 60 revolutions per minute. This fan had been two years in constant work, without requiring any repair, and appeared in as good order now as at first starting; the cost of working, as compared with the old imperfect furnace ventilation, was remarkably small, the fan saving certainly 9-10ths of the fuel consumed by the ordinary ventilating furnace. The efficiency of the air valve covering the top of the pit was an unexpected result, and simplified the construction of the apparatus considerably. It had been thought originally that two air valves would be required, to prevent loss by drawing in air direct from the top of the pit, and double valves had consequently been provided; but this provision was found unnecessary, as it appeared that a column of air of so great length, extending over 12 or 15 miles through the mine, when once set in motion, was not perceptibly affected by a slight check at the end of its course, and was not disturbed by the passage of the cage in and out of the mouth of the pit; the simple flat door at the top accordingly answered the purpose completely. In the erection of subsequent fans the construction might be farther simplified by the substitution of thin stone or brick walls on each side of the fan, in place of the present iron casing, with the advantage of cheapness and facility for renewal or repair.

The Chairman observed that the plan now described appeared to be far superior to the ordinary system of furnace ventilation, in which a large furnace was kept burning at the bottom of the shaft, so as to rarefy the air and make the requisite draught up the shaft to draw the current of air through the mine. Such a method was unavoidably attended with continual variations in the current of air through the workings, as the fires fluctuated according to the brightness or dullness of burning at different times, and the ventilation was directly affected by irregularities in keeping up the fires and variations in the state of the atmosphere. The use of jets of steam for ventilation, proposed by Mr. Gurney, had recently been in favour, the steam acting in the same manner as the blast in the chimney of a locomotive engine; he enquired what was the general result of this plan, and whether it was now in regular work.

Mr. Rogers thought the employment of steam jets must always be an imperfect and expensive mode of applying steam power for ventilation; it was much preferable to apply the steam direct to work a fan, by which means a low pressure of steam could be made fully available. He did not think the plan of steam jets was continued in practical use; one serious objection to it, that was experienced when tried on a large scale, was the constant shower of water caused by condensation, from the large quantity of steam thrown into the air shaft.

Mr. Hawkes asked what degree of vacuum in inches of water was obtained by the fan ventilation, and how the velocity of the air had been estimated. From ½ inch to ¾ inch of water was, he had found, the ordinary vacuum obtained in stationary engine chimneys.

Mr. Rogers had found in his own experiments from ½ inch to 1 inch of water pressure, according to the speed of the fan; he had tried the vacuum by means of a water gauge, and had also estimated the velocity of the air by Dr. Hutton's theoretical calculations. The results had been checked by Biram's and other anemometers, and had been found to agree very well. A third test had been tried by firing powder at measured distances in the workings by means of a voltaic battery at the surface, the time of passage of the powder smoke to the surface being noted by a watch.

Mr. Hawkes asked what amount of vacuum was obtained in the ordinary furnace ventilation of collieries.

The Chairman said that the information on this point was very imperfect, from the uncertainty about the experiments; he supposed the vacuum was generally below 1 inch of water, perhaps considerably less: but in large deep mines a vacuum of as much as 2 inches of water was sometimes required to overcome the resistance to the current in the workings.

Mr. Rogers remarked that there were several disturbing causes to be taken into consideration, and great precautions were necessary in ascertaining the vacuum correctly. The barometer showed 1 inch difference of height at the top and bottom of a deep shaft, such as that at Abercarn of nearly 900 feet depth, where it stood at 29 inches at the top, while it showed 30 inches at the bottom. The particulars of the height of the barometer and difference of temperature had been noted in his experiments, and were given in the table appended to the paper, together with the degree of vacuum arising from the natural ventilation due to the difference of temperature, which amounted to about ¼ inch of water.

Mr. **Shelley** enquired whether the distance of the fan from the pit mouth and its relative position were material for its good working.

Mr. **Rogers** said the distance of the fan from the shaft was immaterial, provided that the air passage from the pit to the fan was of the full size, free from contractions or obstructions. All that appeared requisite was to make the fan large enough to have an ample margin of surplus power of ventilation, without requiring a high speed of working; and from the results of his experience he should certainly recommend in future a considerably larger size of fan, probably as large as 21 feet in diameter.

Mr. **Hawkes** mentioned that a species of fan for ventilation had been tried many years ago by Mr. Brunton, acting somewhat on the principle of a screw, to which allusion had been made; but he was not aware what results had been obtained with it. He remembered that Mr. Nasmyth had read a paper on the subject of ventilating fans at the meeting of the British Association at Ipswich several years ago, but thought the arrangement then proposed was different from that now described.

The **Chairman** asked what was the construction of the ventilating fan at Mr. Powell's colliery in South Wales, which was probably the one referred to as Mr. Brunton's, and whether it was at work now or had been given up.

Mr. **Rogers** replied that was the fan on Mr. Brunton's plan, and he remembered seeing it first put to work about nine years ago; it was a horizontal wheel about 9 feet diameter covering the top of the air shaft, with a large number of vanes set inclined like the vanes of a windmill or the blades of a screw; the air had access to the vanes on the underside, and was expelled from the upper side of the fan. The plan was found to be imperfect and unsatisfactory as a means of ventilation, and he believed it had been entirely abandoned. In the paper read before the British Association that had been referred to, Mr. Nasmyth proposed a fan only about 4¼ or 4½ feet diameter, which was so small a size that it would not have at all answered the purpose. The large size of the present fan was the most important feature in the improvement, by which indeed the practical difficulties had been overcome. The whole credit of the calculations and arrangements in the form of the present fan was due to Mr. Nasmyth, and they were founded on the results of his experience; there might no doubt be many modifications of the form and proportions of the different parts of the fan, but these did not appear to be material points, and the simple construction that had been described appeared practically as good as any. He might mention that the plan had been thrown open by Mr. Nasmyth for general use, without reserving any exclusive right in it.

Mr. COCHRANE thought a great feature in the plan of fan ventilation was the simplicity of the apparatus, and the smallness of cost, and also the applicability to deep mines; the great freedom from risk of derangement was an essential point, removing the objection ordinarily urged against ventilation by mechanical means. Any plan which tended to preserve life was of great value, and the fan ventilation was certainly an important step in the right direction; great credit was due to Mr. Rogers for investigating the subject so completely, and making such a thorough practical trial of the plan. There was no doubt this fan was doing the work of ventilation admirably, and he thought surpassing all other plans, and it required only to be better known to be extensively adopted; they were greatly indebted to Mr. Nasmyth for effecting this valuable improvement in the mode of ventilating mines.

Mr. ROGERS observed that the power of suddenly increasing the current of air through the workings in any emergency was a great advantage over the ordinary furnace ventilation, in which no such change was practicable. He was convinced that the majority of deaths from explosions resulted from the suffocating effects of the after damp, and not from injuries occasioned by the explosion itself; and in cases where men recovered after an explosion, it was observed that a quantity of black carbonaceous matter, or "coal dust" as it was termed by the miners, was first thrown off the lungs; this was the result of the deposition of carbon in the atmosphere that had been inhaled; for every 45 volumes of fire damp, which was a mixture of carburetted hydrogen and air, produced in the explosion 2 volumes of vapour of carbon, which was precipitated in the form of minute black flakes filling the air. In the case mentioned in the paper, the result of suddenly turning the steam full on to the engine of the fan was remarkable; an immense volume of air, probably 70000 or

80000 cubic feet per minute, instantly swept through the works like a hurricane, and carried off with it all the particles of carbon precipitated in the air. With the furnace however the ventilation might have been deranged by the explosion, and thus made more certain of failing at the very moment when most needed.

The CHAIRMAN remarked that another advantage in the fan, that had not been directly alluded to, would be the uniformity with which the ventilation was constantly maintained; he had no hesitation in saying that the loss of life from bad ventilation was much greater than that from explosions, as the men working in the pit were exposed to bad air constantly, and the effects must tell seriously on their health, when the ventilation was defective for any length of time, which was liable to be the case frequently with the ordinary mode of ventilation.

Mr. RAMSBOTTOM thought the fan an exceedingly perfect machine; the leading feature in the mechanical arrangement appeared to be the enlargement of the fan to a size admitting of direct action of the small steam engine by which it was driven, the engine working at the same speed as the fan, thus dispensing with any intermediate gearing, and reducing the whole to the simplest form of machine, which could be readily kept in good working order. A second cylinder might easily be applied if desired at the other end of the same shaft, which would render any stoppage from the failure of the working parts next to impossible.

The CHAIRMAN proposed a vote of thanks to Mr. Rogers for his paper, which was passed.

The following Paper, by Mr William Walker, of Lincoln, was then read:—

ON THE APPLICATION OF STEAM POWER TO AGRICULTURAL PURPOSES.

II. BARN MACHINERY.

The steam engine having been called in to aid the farmer, it has been found, as shown in the previous paper under the present title, that an engine on wheels, portable and self-contained, is the most eligible form for that purpose, unless in large farms where a fixed engine might find full employment. The introduction of the portable engine and its history having been the subject of the former paper, the writer proposes now to consider the "Barn Works," or implements employed on the farm, either fixed or portable, and in general use with a steam engine.

The machinery of a farm may be divided into the following classes, besides the driving power:—

The Threshing and Dressing apparatus for grain.
The Mill and Flour Dressing apparatus.
The Corn Crushing, Straw Chopping, and Root Cutting implements.

These are called the barn works, and to them may be added the sawing machinery; but as this is not properly an agricultural implement, though of great service to the farmer, it is passed over. These implements, and the methods in which the work is performed, with a retrospective glance at their earlier history, form the subject of the present paper. The writer therefore proposes to review briefly the history of the threshing machine, and, following the grain in its preparation for food, to notice the corn dressing machine, the mill and the flour dressing machine, as well as the minor auxiliaries of a farm, without attempting to particularize the small practical distinctions of manufacture, but treating them in general terms, as also the several processes admitted by all to be necessary.

Precedence in date of history as well as in order of process must be given to the Threshing Machine. The most important process in agriculture in early times was the beating of the corn from the husks, and this required more ingenuity than the preparation of the soil in the fertile countries to which the oldest records refer. Mention is made in very early history of the threshing floor, and of threshing instruments of wood and iron and implements armed with teeth; the flail, drag, and wain, and the method of treading by cattle, are also particularized.

The Threshing Floor was a round level plot of ground, made hard and smooth, for the purpose of threshing or separating the corn from the straw, by the treading of oxen or other methods.

The Flail or Staff was used for such grain as was too tender to be treated in other methods.

The Drag consisted of a frame of timber or strong planks, roughed at the bottom with hard stones or iron, and was drawn by horses or oxen over the corn sheaves placed upon the threshing floor, the driver riding upon it. In 1848 there was in use in Palestine a drag or threshing machine composed of two thick planks fastened end to end, the smaller plank in front being bent upwards; holes were bored in the underside of the planks, and sharp pieces of stone or iron points inserted in them. This instrument cut the straw as well as separated the grain from it, and was drawn by oxen, horses, mules, or asses, driven in a circle over the grain or sheaves by a man seated upon it; large stones or heavy pieces of wood were also put upon it to increase the weight.

The Wain was a similar machine, driven in the same manner, composed of three rollers armed with iron teeth, or wheels saw-edged all round to cut the straw. The *moreg*, as this implement was called, was in use in Egypt in 1838.

Treading the corn was still carried out in 1844 in the South of France at Avignon, and a similar plan was used in Virginia. The manner of operation is the same as in the other methods; the sheaves are opened and spread out thickly in a circle or ring on the threshing floor with the ears uppermost, and the animals are driven quickly over by a man in the middle, who guides them by halters, while other men shake up the corn. The floors are from 60 to 100 feet in diameter, and the horse track from 12 to 25 feet wide; the floors are sometimes fenced in, and then the animals are driven loose. The grain after being thus threshed from the ear has to be separated from the chaff and dirt, as well as the dung of the animals, whose legs are much injured by the process; the grain is also broken. In the present year horses and oxen were used in Hungary for treading out the corn; and in one instance, in August last, this plan was being used at the same time as the new finishing threshing machine.

There is another instrument also described as being in use in Syria in 1848, a kind of sledge drawn by one horse, having a wooden cylinder about 4 feet long and 2 feet diameter fixed horizontally under a platform mounted upon wheels; on the cylinder, which revolves as a wheel, are fixed about 1 foot apart two rows of sharp blades somewhat like hatchet heads, which turn within 4 inches of the ground. This is driven by a man seated on it in a circle or ring over the sheaves of corn, fresh sheaves being constantly fed to it, and the crushed corn gathered up by men on the outside of the ring.

The use of oxen seems to have been almost universal, as well as the system of treading out the corn; but in China this process was generally performed by means of a heavy roller of unpolished marble. In the vicinity of Canton the flail was used ten years ago, but whence imported is not ascertained. There does not appear to be any trace of the *tribulum* or Roman threshing machine in this country; but the flail (*fustis*) or staff was known to the Romans, and is supposed to have been introduced by them. The fustis is understood to have been a plain rod similar to that of the Jews, and the loose beater to have been introduced subsequently to the Norman Conquest; the implement then became substantially the same as that now in use.

It will readily be conceived that in this country, where the flail was in every-day use and almost the only implement used for threshing, any first attempts at innovation, such as the application of power to attain the same object, would be by means of a similar instrument. Accordingly in 1732 Michael Menzies, an advocate residing in East Lothian, invented a threshing mill, of which we have but a very rude outline in the "Gentleman's Magazine" for February, 1735. It consisted of a number of flails fixed in a wooden beam or shaft, which received motion by means of a crank from a water wheel and shaft making about 30 revolutions per minute: the beam is said to have been moved backwards and forwards with the flails inclined to it at an angle of ten degrees; but how they were inclined so as to be suitable for working backwards and forwards is not told, and the description is necessarily imperfect. The beam is understood to have been placed across the floor horizontally for the flails to fall on the straw, and is said to have given 1320 blows per minute; this would then be by means of the rocking motion given to the beam, and dependent upon the number of flails fixed in the beam. The machine is stated to have been fixed at Roseburn, and the description of it in the transactions of the "Society of Improvers in the Knowledge of Agriculture in Scotland" is allowed to be the earliest published account of a power threshing machine; it is noticed in Brown's subsequent work on "Rural Affairs," 1811, where it is stated that the force soon broke the flails and hence the machine did not succeed.

This application of power was of the simplest description, there being no attempt at modifying the mode of operation in the work to be done so as to suit the peculiarities of the new power. It is very interesting to notice the progressive development of the new system, which has after an interval of one century been brought to such perfection as to have practically superseded the old method of threshing by hand. It may however be here mentioned that many parties prefer barley for malting purposes still threshed by hand: whether there is any reason for this preference the writer does not know, but the condition of the wheat and barley threshed by the machines certainly proves the efficiency of the new system.

In 1758 Michael Stirling, farmer, Dunblane, invented another machine having a vertical shaft with four cross horizontal arms working in a case 3½ feet high and 8 feet diameter. In this case the shaft with the arms was turned at a considerable velocity by a water wheel; and the corn being gradually let down through an opening at the top of the case, the grain was beaten out by the arms and passed through an opening in the floor along with the straw, from which it was separated by fanners also worked by the vertical shaft.

In 1772 Ilderton and Smart constructed a machine to act by rubbing the grain from the ears instead of beating it out. The sheaves were carried between a horizontal indented drum about 6 feet diameter and a number of rollers of the same description, ranged round the drum and pressed towards it by springs, in such a way as to rub out the grain when the drum was turned round.

In 1778 a machine invented by Mr Oxley at Flodden was erected for Sir John Delaval. This machine had two fluted feeding rollers; and, instead of a drum, had two sets of arms keyed on a horizontal shaft, the ends of the corresponding arms in each set being connected together by crossbars parallel to the shaft. The scutchers or beaters were formed of two pieces of wood 3 inches broad by 1½ inch thick at one edge and ¾ inch thick at the other, and were attached to the crossbars by leather straps. A circular breastwork was placed about 3 inches from the beaters, so as to allow the corn to pass between; the unthreshed corn was laid on a board at the level of the centre of the beaters and drawn in by the fluted rollers. The operation was defective and slow, and more expensive than with the flail; the machine was never made public, and its abandonment after trial proved its inutility.

In 1776 Andrew Meikle, a millwright at Houston Mill, Tyningham, East Lothian, attempted to construct a machine similar to that of Menzies, but his plan was soon laid aside. Sir Francis Gilmerton, having seen Ilderton's machine, had a model made under his own directions, which was sent to Meikle to try by means of the water wheel at his mill; but the model was torn to pieces in the experiment, and the same fate befel a similar machine of full size subsequently made for one of his tenants; it could not sustain the requisite velocity, and was therefore laid aside. Meikle's attention was then drawn again to the subject, and he concluded that it was necessary to adopt a rotary motion to beat out the grain, by means of a drum or cylinder on which were placed beaters shod with iron. He made a model in 1785 and a machine in 1786 on this principle, retaining the fluted feeding rollers of Osley's machine. This machine was fixed for Mr. Stein, of Kilbeggie near Alloa in Clackmannanshire; it may be said to be the parent of our present threshing machines, and is the same which in an improved form is now in use.

In 1796 John Steedman, of Toft's Farm, Trentham, Staffordshire, patented a threshing machine, the features of which were a "flail barrel," on which were ten or twelve flails set in motion by the turning of the barrel, the sheaves being placed on a circular moving floor to receive the strokes of the flails. This was the first machine contemplated to be worked by steam, and the writer believes it was so tried; but it did not stand the test of practical working, and thus left Meikle's machine to prove its superiority.

Meikle added blowers or fanners to clean or dress the grain; shakers to toss the straw, made like rakes fixed on drums; gratings for the corn to pass through; and elevators to lift the grain. These are all in use now, and Meikle's was accordingly the *first practical threshing machine* and the *first combined machine.*

Having now brought the threshing machine down to the point where we may assume the principle to be determined and practically developed, the mode of preparing the grain after being threshed presents the next topic for consideration. The earliest method is supposed to have been by tossing the grain in the air, the wind carrying away the chaff while the grain fell to the ground; and for that purpose the threshing floor was generally situated on high ground, well exposed to the wind. The fan or winnower is specially mentioned, and is supposed to have been a similar hand fan like a shovel with a handle, as used by the Romans and still in use in oriental countries to cause a current of air. The grain was thrown into the air or dropped from an elevation and a current of air set in motion by the fan carried off the lighter particles of chaff. Sieves for sifting the corn are also noticed, but in these the corn remained, while the dirt and seeds fell through.

Winnowing machines were first introduced into Scotland in 1710 or soon after, but were not generally known to farmers till 1733; while the vibrating riddle and fanner were brought forward by Dr. Stephen Hales in 1745 in nearly their present form. In the Western Highlands of Scotland in 1849 there was in use a fan or shovel made of sheepskin stretched on a hoop about 2 inches deep, two sieves or riddles being also used for the grain; the person using these holds the sieve up with the corn in it, and wafts the grain with the fan as it falls through, thus driving all light substances away from the heap on which the corn falls.

In 1735 Dr. Desaguliers from Holland brought under the notice of the Royal Society of London a contrivance called the centrifugal machine or bellows, based upon Papin's machine for blowing or extracting air in a continuous blast; and the application of a similar machine to dressing corn is noticed in the "Gentleman's Magazine" for May, 1747.

Dr. Hales in his work, 1745, describes what he calls a "back heaver," consisting of a riddle put in motion with a current of air from a fan, similar to the present riddle.

The Combined Threshing Machine consists of machinery to effect the several processes of threshing, shaking, riddling, winnowing, hummeling, elevating, separating, and sacking by weight or otherwise; the machine being all carried on one frame, and the whole put in motion by one belt from the engine.

The first portable threshing machine on wheels driven by steam was made by Messrs. Tuxford of Boston in 1842, with an engine on the same frame, as noticed in the former paper. The first portable combined threshing machine was also brought out by them early in 1844, for Mr. George Holland of Carrington, the combination in this case consisting of one other part besides the threshing drum. Of fixed barn machinery, Messrs. Clayton, Shuttleworth, and Co., of Lincoln, with whom the writer is connected, were among the earliest makers, the first fixed machine being made in 1852, previous to which however several portable machines had been in effect fixed; in 1854 by a simple contrivance the corn was dressed twice at one operation in the portable machines constructed by them; and in 1855 the machine was made to finish and dress it for market, separating the quality of the corn in a manner about to be described, and producing a superior sample. In this way from time to time the threshing machine has been modified and improved, and more parts added; and instead of the several processes being performed by so many separate machines, they are now combined on one frame, thus giving the name to the machine.

Of Mills and Grinding little need be said; the rotary motion seems to have been early adopted, and hand mills were part of the household fittings in the East. Women used to grind, generally two at one mill. Similar mills, called "querns," were in use in Scotland till 1830; and hand mills of a similar description worked by women are in use in India in the Hindoo towns and villages, as also in Abyssinia. Little alteration has been made in the plan of doing the work, but steam and other power is now largely applied. Wind power was common in Spain in the sixteenth century, and is supposed to have been introduced into France in the sixth century for the purpose of grinding corn. Of the earlier use of power for this purpose the writer cannot obtain conclusive evidence, nor of the first application of steam power to the mill.

The Flour Dressing Machine was invented in 1675 by John Milne, the earlier method having been to sift it through "bolting cloths;" he constructed a cylinder of wire, and claimed the use of brushes, arranged either parallel to the axis of the cylinder or forming a screw or worm, the brushes revolving in the cylinder, or the cylinder round the brushes, or both revolving in opposite directions. A brief description of those now in use will be found to be identical with this machine.

The writer will now proceed to describe in detail the various processes through which the corn goes, and to notice the principal features of the machines in actual use at the present time.

Fig. 1, Plate 91, shows a longitudinal section of a Portable Thrashing Machine. The sheaves of corn having been unbound are passed to the feeder, who stands in the dickey A, and shakes the straw loose into the mouth of the machine B; here it meets the drum C revolving at a high velocity, which carries it over the concave or breastwork D, beating out the grain from the ears. The grain falls through the breastwork D, while the straw is thrown off into the chamber E, whence it is taken forward by the shakers FF, and thrown over the straw board G. The shakers F by their motion also separate the straw, and allow any grain that may have been thrown off from the drum with the straw to fall on to the shock board or shogging board H, whence, by means of the motion given to the shogging board from the crank shaft I through the connecting rod J, it is passed down to the riddle board K, to which an opposite motion is communicated by the other connecting rod L from an opposite crank on the shaft I, the two boards H and K advancing to each other or receding simultaneously, both being suspended by links to the framing and swinging loosely between the sides of the machine.

The grain that passes through the breastwork D is guided by the bent plate M so as to fall upon the top end of the riddle board K. In working the machine many heads and short straws fall from the breastwork and shakers, and a coarse riddle or perforated plate is put on the top of the riddle board K to take them out from the corn; these "cavings," as they are called, pass over the end of the board K and fall down the caving board N. The corn and all smaller substances, chaff, &c., pass through the top riddle and down an inclined board on to a second riddle O of a finer mesh or perforation; here they meet a blast of air from the fan or blower P, which blows away the chaff through the opening Q, while the grain which is heavier falls into the spout R.

The grain is thence carried away by the elevator S, Figs. 2, 3, and 4, Plate 92. This is composed of a number of tins or cans T fixed on a belt U, which works over two pulleys VV, one at the top and the other at the bottom. The spout R of the thrashing machine delivers the corn into the bottom shoe of the elevator; the cans T being carried round by power applied through a belt to the spindle of the top pulley V take up the grain, and in turning over the upper pulley discharge it into the spout W, which forms a hopper for it; thence it passes to the next process.

The drum C, Fig. 1, of the thrashing machine is shown in four modifications in Figs. 8 to 15, Plate 93. That shown in Fig. 8 is composed of rings A supported by arms B; on these are fixed the wood beaters C shod with iron, having a filling piece D, also plated with iron, inserted in front of each beater, to prevent the straw being carried round with the drum instead of being passed away. Fig. 9 shows a close drum made of plate arms B and angle iron, with angle iron beaters C having wood supports. Fig. 10 represents a drum now in use, having wood beaters C, over which wires E are strained; on the top of these are bolted the beater plates F, which are grooved in the face, as shown in Fig. 11, the object of the grooves being to allow the grain to pass into them, and prevent it from being broken as was the case with plain straight beaters.

The breastwork D, Fig. 1, is shown in detail in Fig. 10. It consists of a frame made in two portions, the upper part from G to H being of wood, and the lower part from H to I of iron; these are carried by iron rods passing across the machine at the three points G, H, and I, which afford the means of adjusting the position of the breastwork by means of screw adjusting pieces at the sides of the machine, so as to bring it nearer to or farther from the drum, as may be required. The adjustments at G and H being horizontal sliding adjustments, and that at I vertical, a slot J is required at the outer extremity of the frame, in which the rod I works. The distance between the breastwork and drum is gradually contracted from the top towards the bottom, to ensure the whole of the straw being exposed to the action of the drum; this distance is sometimes about 1½ inches at the top and reduced to only ¼ inch at the bottom, but the adjustment is dependent upon the state of the grain. The upper half of the breastwork is furnished with transverse strips or ribs of wrought iron K, about 1½ inches wide by ¼ or ⅜ inch thick, let in to the sides of the framework; these are perforated with holes, through which a set of wires are passed, forming a concave grating to prevent the straw from getting through. The lower half of the breastwork is a frame of iron bars D also covered with wire. Strips of bar iron L rolled with one or two longitudinal grooves are fastened on the wooden frame of the breastwork, projecting slightly to prevent the straw from passing too quickly without being thoroughly threshed. The straw is guided from the breastwork to the shakers by the plate M.

Another plan of breastwork, invented by Messrs. Barrett, Exall, and Andrewes, of Reading, is shown in Fig. 12, formed by a series of flat bars D, held in their places by the sides of the machine in which slots are cast; the bars are all moved together to or from the drum A by a worm plate E, Figs. 13 and 14, in which their ends rest, and are thus adjusted to the required distance from the drum. The plan of drum adopted in connection with this breastwork is also worth noting, as being new, simple, and efficacious. Three or more sets of arms B are keyed on the spindle, each set being completed by a hoop A on the outside, on which are fixed the wrought iron beater plates C, of the form shown in Fig. 12. The beater plates are made of flat iron, rolled or pressed into the shape, with the spaces F cut in, as shown in Fig. 15, so that any grain they may collect may pass into the drum until it can find its way again to the breastwork D. This beater seems to be more perfect in its mechanical construction than the others where wood and iron are used together.

Figs. 16 to 21, Plate 94, show three modifications of the straw shaker F, Fig. 1. Figs. 16 and 17 represent side elevations and end elevations of the two positions of a "rail shaker," which was made of a number of rails or bars FF attached alternately to two frames GG, actuated at both ends by the two crank shafts HH; the shafts H were also coupled together by means of cranks on their outer ends and coupling rods. Figs. 18 and 19 show a "box shaker," consisting of a set of boxes FF covered with perforated sheet iron, or with sloping strips of thin hoop iron, as shown dotted; the boxes are carried at one end by radius links G, and the other ends are attached to double cranks on the shaft H which give the alternating movement, the boxes thus rising and falling to receive or deliver the straw the one to the other, and the rotary motion of the cranks also carrying it forwards as in the former case.

An improvement upon these two methods is shown in Figs. 20 and 21. The great fault of the rail shaker consisted in its passing so many straws through, while the objection to the box shaker was that any grain that had been thrown by the drum to the outer end of the chamber E, Fig. 1, was carried along with the straw over the end of the shaker, in consequence of the vertical motion of the crank being reduced at that point and becoming only a horizontal or longitudinal motion at the end. To obviate these defects the new shaker, Figs. 20 and 21, was invented by Mr. James Good, of Lincoln. The principle on which this is constructed differs from that of the ordinary box shaker, Figs. 18 and 19, in this respect, that while the latter has the crank bearings at the same end for all the boxes and the radius links G at the other end, in the present shaker the boxes are supported by the links alternately at opposite ends, the crank shaft H being thus between the links G; or in other words, the crank shaft H may be said to be moved to the middle of the length of the boxes, and half of the boxes to be then turned round end for end. Thus while the ends that are attached to the links close to the drum rise only so much as is due to the vibration of the rocking links, the ends of the other boxes have a considerable lift imparted to them from the crank; in the centre of the length of the boxes just over the crank shaft H the lift and throw are the same as in the most effective part of the old shaker; and again at the outer end the straw is tossed by the loose ends of the boxes, while only a passing or horizontal motion is given by the others. This is known as the "cross shaker," owing to the boxes moving crosswise, or alternately up and down. In the shaker shown in Fig. 1 there are five boxes, two working on links at the end of the machine, and the three alternate boxes vibrating on links at the end nearest the drum; the inner ends of the latter are prolonged, to allow for the throw of the crank, and are attached by means of an angle iron to a cross bar Z extending across the machine and carried by two links outside the framing, one on each side, as shown dotted, thus avoiding any links inside the machine.

There is another shaker, invented by Messrs. T. and H. Brinsmead, of St. Giles', near Torrington, Devonshire, which is worthy of mention, as the features of it are so different from those of every other shaker. Immediately over an inclined plane of wood, and sufficiently above it to allow them to revolve without touching it, are placed transversely and therefore horizontally a series of triangular prisms of wood, armed at their edges with curved iron teeth, so arranged that as the prisms revolve the teeth of each pass between those of the two adjoining prisms. The prisms being made all to revolve simultaneously in one direction, either by cranks on the ends of the spindles coupled together by one rod, or by a train of wheels, the straw which falls on those at the lower end of the plane is tossed and carried upwards by the action of the teeth as they rise, which also, as they pass down again between the teeth of the prism next above, deliver the straw on to these last, and sweep down to the bottom of the plane the corn and any short straw that has fallen through. At the bottom of the plane is a curved wire netting through which the corn readily passes, but which stops the passage of any straw; and the revolving teeth of the lowest prism rake up the straw again as it accumulates, and toss it upwards and onwards as at first.

The shogging board H and the riddle board K, Fig. 1, were originally in one length; and the vibration then caused by this single piece moving backwards and forwards impeded the introduction of portable machines. They were first parted into two lengths, as shown in Fig. 1, by Messrs. E. and T. Humphries, of Pershore, to whom may be fairly given the credit of making the portable machine the useful and steady farm implement that it has become. In the present machine the motion of the two boards in opposite directions neutralises the disturbing effect of the reciprocating weight of both.

The elevator S, Figs. 2, 3, and 4, has been already described in a form generally in use. Another kind of elevator also in use is formed of sheet iron bent round a spindle in a spiral form, working in a trough curved to the radius of the outside of the worm and touching it; thus winding the corn, &c., that falls into the trough by means of the worm up the spout; but as it must necessarily be kept at only a slight inclination, this elevator is not so general in its application as that previously described, nor nearly so cheap in construction. It is used in the American machines and by Messrs. Hornsby and Sons.

From the spout W, Figs. 2, 3, and 4, the grain is delivered into the hopper X of the Corn Dressing Machine, and thence into the barley horner Y, which is shown more fully in Figs. 22 to 25, Plate 94. It is here subjected to the action of a number of knives fixed on a spindle, which loosen the husks or whites of the wheat and cut the ears or horns off the barley. Independently of the inclined position of the barley horner, the grain is kept in motion by the "set" of the knives, which are in a spiral form. Motion is given to the spindle by a pulley fixed on the end.

The grain and loose ears pass from the barley horner into the mouth B of the dressing machine, and are met in their descent by a current of air from the fan or blower P, which clears the grain of all chaff and ears that may have been left in it; the grain falling upon the inclined board M is conducted to the riddle K, which is carried upon the links AA, Fig. 2, and has motion communicated to it by the crank at the end of the spindle C. Any stones or ears that may have got in are here taken out, and pass over the riddle K into the spout D, whence they are conducted into the delivery spout E. The grain on falling through the riddle is caught by a fine wire sieve O, through which all small seeds pass and are carried also to the spout E. The grain passing over this sieve is swept by a current of air taken from the back of the blower P by the passage F, by which it is effectually cleaned of any lighter seeds that may be too large to pass through the sieve, and also of any chaff that may have been loosened from the grain by the riddling. The board G carries the grain to the mouth of the revolving sieve or screen H, which receives a rotary motion from the wheels J. The small imperfect corn, or "light" corn, falls through the first meshes into the spout L; the mesh being then altered and widened allows the broken corn and a larger size, or "tail" corn, to fall through into the spout N; while nothing but the best corn can find its way to the spout Q. A simple apparatus is here fixed, consisting of a weighing machine with rods and bell cranks so arranged as to shut off the delivery and ring a bell when the scale falls. A bushel of corn weighs 60 lbs., and four bushels make a sack; and the weight of the sack itself being 7 lbs., 247 lbs. is therefore the weight to be put in the scale; and the empty sack is held open to the spout Q by means of rods fixed on this scale of the machine. When the four bushels of corn are delivered the scale falls, loosing the catch of the slide, which immediately shuts and allows a bell that has hitherto rested upon the top of it to swing clear and ring, thus calling the attendant to put a fresh sack on and re-open the slide.

The whole process, from the time when the corn in the straw is fed to the threshing machine, Fig. 1, to the time when the grain dressed and sorted for market is sacked in half-quarter quantities from the spout Q, Fig 4, is thus entirely self-acting; and in this time the following separations are made:—straw—cavings—chaff—seeds—light corn—tail corn—best corn; —besides dust, which must inevitably be mixed up with the straw at first, and which is blown away in the process.

The Portable Threshing Machine is now so arranged as to combine the dressing and separating process with the threshing and winnowing in one machine; and a brief description of the Combined Machine will suffice to explain the arrangement.

The riddle boards K and O, Fig. 1, are divided longitudinally and vertically into two parts, as is also the blower or fan P, thus forming two distinct sets of blowers and riddles. The corn passing through the first set, as in Fig. 1, arrives at the spout R as before described, from which it is taken up by elevators and passed into the hopper of a barley horner Y placed under the dickey A of the portable machine. It is thus passed to the other side of the machine, where it falls down in front of the second half of the divided blower, corresponding to the blower P in Fig. 4, upon the new or second set of riddles, corresponding to the riddles K and O in Fig. 4, down to a second spout corresponding to the spout R on the other side of the machine. It is here again taken up by another set of elevators and discharged into the hopper B, Figs. 5 and 6, passing through the revolving screen H, and being delivered as before, the light corn by the spout L, the tail at N, the best at Q, and the seeds and dirt at EE.

In this separator a blower P is fixed either above the machine and screen case H, to blow all chaff and seeds out before passing into the screen, as in Fig. 5, or at the end, as in Fig. 6. The latter plan, shown in Fig. 6, is the invention of Mr. Nalder of Alvescot, Oxfordshire, the corn being subjected to the action of the blast while on the screen and in falling from it. The arrangement however shown in Fig. 5, by Messrs. Clayton, Shuttleworth, and Co., of Lincoln, is found to be an improvement, and has been adopted in place of the other arrangement in their machines. The plan first tried was to blow up the screen; then under; then up and under; but in the last plan, shown in Fig. 5, the chaff and light corn are blown out before reaching the revolving screen H, and consequently power is saved; and experience shows that a better sample is obtained by this arrangement. In both the plans shown in Figs. 5 and 6 brushes ZZ are fixed above the revolving screens H to keep the wires clear. The separating apparatus is fixed on the side of the portable threshing machine, and the grain is delivered in the same separations as enumerated previously.

The action of threshing is still supposed by many to be a continuous series of *blows*; by others to consist of *rubbing* between the beaters and the surface of the breastwork; and by others again to be the combination of the two actions.

In the present machines in this country the straw is fed across the drum so as to allow the drum to "boult" it, or carry it through without twisting or breaking the straw, which is with many farmers a serious consideration. In the old machines, and in the present American machines, the straw is broken up by means of pegs on the drum and breastwork; but as the Royal Agricultural Society take notice of the state of the straw, whether it is broken or not, it has become an object to preserve it.

With regard to the riddles, the top riddle plate K, Fig. 1, is coarse in the openings, to allow the corn to pass through freely; the second riddle O is finer; and in the combined machines with the split blower and riddles the third and fourth riddles, corresponding to K and O in Fig. 4, are each finer than the one before it. The riddles are sometimes made of wire netting, and sometimes of wood perforated at an inclination, as invented by Messrs. E. and T. Humphries, of Pershore; but more frequently of punched sheet iron.

The next process through which the grain has to pass is grinding, breaking, or kibbling, as it is called, according to the degree of fineness of the meal required. Several methods have been proposed, but the old plan of one stone revolving above another which is fixed is still found as good and economical as any. Fig. 7, Plate 93, shows a vertical section of a Portable Corn Mill constructed on this plan. The corn being fed into the hopper A is shaken down the spout B by the damsel C, working against the spout, into the eye of the upper or running stone D, whence it gets into the furrows of the two stones D and E, passing out from them as meal into the casing F, from which it is carried off by the spout G. Motion is given to the runner D from the pullies H through the shaft I by means of the mitre wheels J to the vertical spindle K; at the top of the spindle are two studs, on which rides the casting L, which also in its turn carries the running stone D by the two steps O. The damsel C being fastened in the casting L receives motion from it. The bed stone E is adjusted by the set screws MM; and the screwed wedges N keep the wood packing against the spindle K. The coarseness or fineness of the meal is regulated by the hand wheel P working a worm gearing in the worm wheel Q, which is keyed on the top of a brass bush resting in an outer bush or seating, with a square thread cut in the two bushes; thus by turning the wheel P the worm wheel Q causes the inner bush to turn in its seat on the thread, thereby raising or lowering the spindle K and with it the upper stone D. The hand wheel R acts as a nut upon the screw S, raising or lowering the spout or shoe B and thus diminishing or increasing the feed to the stones. The object of these mills on farms is to break wheat, barley, oats, &c., into meal for food for man and beast; it is only worked occasionally, and therefore the arrangements for cooling the flour and meal are out of place here. Several mills with iron and steel plates, edge stones, &c., have been introduced, showing great ingenuity, but they are unavoidably passed over in the present paper.

The Flour-Dressing Machine consists of a case containing an inclined cylinder of wire gauze of various degrees of fineness; on a spindle passing along the centre of this cylinder are fixed by means of arms keyed on it a set of brushes, which revolve rapidly at about 500 to 550 revolutions per minute. The meal or broken corn is passed into one end of the cylinder, and the fine flour falls at once through the wire into the first compartment; by means of the brushes and alterations in the gauge of the wire five or six separations are made, which are called in some—superfine—seconds—thirds—fine sharps—coarse sharps—bran;—in other machines they are called—fine—seconds—thirds—middlings—fine bran—bran;—each having five middlings and the husks or bran. The best corn makes the best description of flour, the tail a coarser sort, and the light corn coarser still; the seeds remain as food for poultry or to be thrown away.

The smaller implements mentioned before as forming part of the barn works are of modern introduction, and have been brought forward by science to assist the practical agriculturist. The following list includes those in most general use:—

Linseed and Corn Crushers.
Chaff Cutters or Straw Choppers.
Turnip Cutters and Root Cutters.
Gorse Crushers or Cutters.
Oilcake Crushers or Breakers.

The Linseed and Corn Crushers have been introduced to effect a saving in the quantity of corn necessary for animals, as the crushing or bruising ensures the whole of the nutriment contained in the grain being rendered available, instead of the animal swallowing the food without properly masticating it. The process is simple; the grain is merely passed between plain or grooved rollers, crushing not grinding being the object; the bulk is thereby increased at least one third, and its nutritive power in the same ratio. This idea is really of very old date, though only of recent adoption, having been recommended by Hartlib in 1650.

The Chaff Cutters are made with two or more knives shaped concave or convex towards the edge and fixed on a shaft carrying a fly-wheel. A feed motion is attached to bring the straw or hay up to the knives, the straw being placed in a box, and the knives working across the end of the box and close against it. The length of the cut is variable, and may be altered from about ¼ inch to 3 inches by adjusting the amount of the feed.

Turnip Cutters are discs, arms, or plates of metal with knives or cutters to pare or slice turnips or other roots, which lie against the knives by their own weight; the roots are cut in slices for cattle, and in strips for sheep, cross cutters being then introduced.

Gorse Crushers are made with toothed rollers to bruise the gorse for feeding beasts which eat it with avidity; it is crushed by the machine to a harmless pulp, and cut into short lengths.

Oilcake Breakers are made with toothed rollers, by which the cake is taken hold of and broken, the cut being adjusted by set screws so as to regulate the degree of fineness required, according as the cake is being broken for cattle or sheep; the dust from the cake passes through a grating.

The results of experience with the several machines have led to the adoption of the following speeds of working as the most eligible for the purpose:—

The speed of the drum of the threshing machine is found to be best at about 5000 feet of the circumference per minute.

The straw shaker should pass the straw at the rate of 75 to 80 feet per minute.

The shogging board and riddle board should be worked at about 200 revolutions of the crank per minute.

The blowers should run at about 2000 feet of the circumference per minute.

The barley horner spindle should make 400 to 500 revolutions per minute.

The elevators should work at 100 to 150 feet per minute, but the rate is dependent upon the quantity to be taken up, and it may sometimes be found necessary to quicken the speed.

The best speed of a 3 feet stone for a mill similar to the one described is found to be about 140 to 150 revolutions per minute, or about 1400 feet per minute of the circumference, instead of 1550 to 1600 feet per minute as given by the ordinary rule, the lower speed giving the greatest quantity of work done for the least amount of power expended.

The smaller machines are not so delicate in their operations, and are more dependent upon the kind of stuff they are fed with and the state it is in, and therefore do not allow of any fixed rule, although each maker recommends a particular speed.

The growth of the threshing machine having been traced from the simple threshing drum and breastwork to the complete machines now in use, an interesting experiment may be mentioned, which was tried at the meeting of the Yorkshire Agricultural Society, at Ripon, in 1854, to ascertain the power consumed by the several parts of the machine.

A combined fixed machine with a dressing apparatus as before described, made by Messrs. Clayton, Shuttleworth, and Co., required 6·15 horse power to drive it when at work, and 1·77 horse power when empty, leaving 4·38 horse power available for doing the work. This machine threshed 200 sheaves of wheat in 13·80 minutes, and the power expended was accordingly 6·15 horse power for 13·80 minutes, equivalent to 84·87 horse power for one minute; or, multiplying by 33000 and dividing by 200, the power expended was—

14004 units of power to thresh 1 sheaf of wheat,

(one unit of power being one pound weight raised one foot high). The 1·77 horse power required to drive the machine when empty was divided as under:—

Dressing Machine	·37 horse power
Elevator	·11
Shaker and Riddle	·28
Blower	·20
Drum and Shafting ...	·81
Total ...	1·77 horse power.

A similar machine made by Messrs. Garrett and Sons required 4·23 horse power to drive it when at work, and 2·70 horse power when empty, leaving 1·53 horse power available for doing the work. This machine threshed 200 sheaves of wheat in 22·68 minutes, and the power expended was accordingly 4·23 horse power for 22·68 minutes, equivalent to 95·94 horse power for one minute; or, multiplying by 33000 and dividing by 200, the power expended was—

15830 units of power to thresh 1 sheaf of wheat.

The 2·70 horse power required to drive the machine when empty was divided as under:—

Dressing Machine	·34 horse power
Elevator	·28
Shockboard and Pulley	·39
Blower and Drum	1·46
Main Shaft and Shaker	·23
Total	2·70 horse power.

The power expended in threshing 1 sheaf of wheat has been gradually increased from about 6000 units in the earlier machines by the additions in successive years of farther apparatus to render the process more complete, several operations being combined in the one machine.

Taking a similar basis of calculation, the power required to work the portable corn mills and smaller barn implements, as reduced from the average results of the trials at the show of the Royal Agricultural Society in 1855, is as follows:—

Portable Corn Mills,	about	9000	units	to grind	1 lb. of corn.
Corn Crushers,	—	3600	—	to crush	1 lb. of linseed or oats.
Chaff Cutters,	—	2200	—	to cut	1 lb. of chaff.
Turnip Cutters,	—	150	—	to cut	1 lb. of turnips.
Oilcake Breakers,	—	180	—	to break	1 lb. of cake for cattle.
	—	350	—	to break	1 lb. of cake for sheep.

The cost of threshing by flail added to the cost of leading the straw, &c., from the stack to the barn was 3*s.* 5*d.* per quarter of corn in 1851, as reported by Mr. Pusey from his own knowledge and at the prices and rates he was himself paying. In threshing with horse machines the cost was reduced to 2*s.* per quarter; but with the engine and portable threshing machine the cost of "barning" is done away with, and the expense, allowing 7*s.* per day for the use of the machine, wear and tear, &c., was reduced to 9*d.* per quarter, showing the important saving of 62 per cent. over the horse machines and 78 per cent. over the hand threshing. A subsequent trial was made at Beverley in 1851, when the actual cost was reduced to 7*d.* per quarter, still leaving 7*s.* per day for the machine; but the nett cost of threshing and finishing a quantity of corn in the method described previously may be said to be now 8*d.* per quarter, this sum including all expenses of dressing the corn for market.

A trial of threshing machines took place in Kent in April last, when one machine threshed without finishing about 21½ quarters of wheat with 340 lbs. of coal in 8¼ hours, while another machine, having extra machinery attached to it for finishing, threshed and finished for market in the same time about 25½ quarters with 364 lbs. of coal, and that under disadvantages, owing to very high wind and the windy side of the stack having fallen by lot to it. A stack of barley was threshed and finished by the second machine in 7¾ hours, including stoppages amounting to 1¼ hour, making the actual time 6½ hours; in this time the machine was found to have yielded 73 quarters of barley, or at the rate of 11·23 quarters per hour; the engine employed was of 7 horse power.

In conclusion, should it be desired to extend the present subject to field operations, the writer will be happy to prepare a paper in furtherance of that object, as it is one possessing such universal interest at the present time and specially requiring the attention of mechanical engineers.

The Chairman had no doubt there were many present, who, like himself, had not often had the pleasure of hearing a paper containing so much interesting matter, and had never been so fully acquainted previously with the history of the various processes. The improvement of agricultural implements and adaptation of mechanical powers had advanced most rapidly in the last few years, and greater progress had probably been made in that time than during the whole period preceding. Mechanical science had never yet been so fully applied to agricultural purposes; and he had no idea, till the present paper was read, that such perfection had been arrived at. The great advance that had been made was well exemplified in the price paid for threshing; it was in the recollection of many that 4*d.* per bushel had been paid for hand threshing, and it appeared that threshing was now done by the machine at the rate of 8*d.* per quarter, or only 1*d.* per bushel.

Mr. HUMPHRIES observed that some farther improvements had been introduced in the details of the threshing machinery, subsequent to those described; an improvement had been made in simplifying the combined motion of the shakers, and working by a crank at the end, causing both ends of the shaker to move up and down. The divided trough or riddle invented by himself had been adopted in consequence of the great vibration occasioned by the single trough previously in use; the whole machine in that arrangement had been caused to rock so violently as to require the frame fixing down to the floor; but by dividing the trough or riddle into two parts moving in opposite directions, the vibration was stopped, the opposite motions counterbalancing each other, and preventing the necessity of staying the machine to the floor, so that it became then really a portable machine.

Mr. HAWKES hoped the author of the paper would continue the subject to field operations, including ploughing by steam and cultivating, which had become now such important mechanical questions.

The CHAIRMAN proposed a vote of thanks to Mr. Waller for his paper, which was passed, and regretted that he had been unexpectedly prevented from being present at the meeting; and expressed a wish that he would give a farther paper on the subject as suggested.

The following Paper, by Mr. Robert Morrison, of Newcastle-on-Tyne, was then read:—

DESCRIPTION OF AN IMPROVED STEAM PILE DRIVER.

The time required for all large works in the vicinity of water is very much increased by the tedious process of pile driving. When it is recollected that an ordinary pile driving machine with four men will rarely drive more than one pile in a day and a half, putting in 1000 piles by this means becomes a lengthy process, and costs in wages alone nearly £800. To reduce in some measure both the time and expense, it is customary to use a small steam engine, and to connect to it the chains running from a number of the old hand pile drivers; but here, although labour certainly is saved, yet the original machine remaining the same, no additional speed is attained.

Upon the commencement of the extensive dock works by the River Tyne Commissioners at Hay Hole, near Newcastle, contracted for by Mr. Thornbury, this difficulty was practically met by the introduction of a direct steam pile driver, designed by the author, of great power, capable of driving a 14 inch square pile 35 feet in 12 minutes in very difficult ground. In fact since it has been in operation the mere driving of the piles has been but a small item in the time; getting up the piles, pointing, and preparing to drive them, now cause the principal delay; and accordingly 21 piles per day are as much as the machine has usually driven. But from what can be done when piles are ready and quickly brought up, there is little doubt but that the machine could easily drive from 30 to 36 piles in 10 hours. The attendance required is very trifling; namely, one engineman, one stoker, and two assistants for pitching the piles; the amount of wages being thus the same as for one single hand machine, with the exception of a few shillings more given to the engineman, whilst the work done is more than 30 times as great, and upon ground on which no hand pile driving machines could make any impression at a depth of more than 16 feet.

The new steam pile driver is shown in Figs. 1 and 2, Plates 95 and 96; Fig. 1, Plate 95, is a side elevation with the steam cylinder in section; and Fig. 2, Plate 96, a front elevation. Fig. 3 is a vertical section of the steam cylinder to a larger scale.

The whole of the apparatus, auxiliary engine, boiler, and lifting tackle, is carried upon one moveable platform AAA, on eight wheels BB, the whole travelling as the work progresses along rails laid on the piles already driven; upon this framework are erected two strong uprights CC, well and securely fitted together, and serving as guides to the hammer cylinders DD. On the top of each of these uprights are two pulleys E and F, the larger ones E for raising the cylinders and placing them on the top of the piles GG, and the smaller ones F for raising and placing the piles themselves; the machinery and gearing for this purpose being driven by a small engine. The pile G is made round at the top and hooped, having a shoulder to receive the collar H, Fig. 3, to which are attached the four columns I I, carrying the cylinder D of the driver or hammer. The piston rod K is made large and forms the weight, and being in one piece with the piston is perfectly secure against all liability to breakage. The cylinder is guided by brackets which embrace iron plates attached to the uprights CC. The steam is conveyed from the boiler to the slide valve case L by a jointed steam pipe M, which allows the cylinders to move up and down as the height of the piles may require.

When it is desired to put the machine in operation, the auxiliary engine N is connected by means of a clutch to the chain barrels O, and the hammer cylinders DD are lifted to the top of the uprights by the chains P, and are there held from moving by a break; the gearing is then disconnected from them by the clutch, and applied to the smaller barrel R on which is wound the chain S. This chain passes over the smaller pulley F at the top of the uprights C, and is attached to the pile, which is thus raised and placed in the position required for driving. This done, the cylinder D is lowered, so that the collar H fits on the rounded head of the pile and rests upon the shoulder; the whole weight of the cylinder is then allowed to rest on the pile, while the strokes of the piston rod or hammer bar K cause the pile to descend, the chain P being then left slack, so as to allow the cylinder to descend with the pile as it is driven.

The apparatus for working the hammer bar is very simple, and consists of an ordinary slide valve in the box L, Fig. 3, the valve rod being connected to a volute spring, the pressure of which tends to hold the valve open, so as to admit the steam into the bottom of the cylinder to raise the hammer bar K. The bottom of the hammer bar has a catch, which strikes the spanner T when the hammer rises, and draws the valve rod down, shutting off the steam from the cylinder, and allowing the steam that has just performed the up stroke to escape; at the same time a small catch U slips into a notch in the top of the valve rod, and holds the valve shut until the hammer has descended and struck the pile. The concussion of the blow causes the lever V at the top of the hammer bar to release the catch U, and the pressure of the volute spring raises the valve, admitting the steam under the hammer ready for another stroke. The process is continued in this manner until the pile is driven deep enough. The auxiliary engine N is then put into gear with the wheels W by means of a clutch, and the whole machine is made to advance; the hammer cylinders are then lifted again, and another couple of piles are raised and placed; and so on till the work is completed.

In consequence of having separate gearing for raising the piles and the cylinders, the piles can be raised up preparatory to pitching, while those previously placed are being driven. Two or more such machines may be used together, or one only employed; and the piles may be driven either upright, or at an angle by altering the uprights as circumstances may require; when at an angle, the steam should be used on both sides of the pistons.

The auxiliary engine N is so arranged that the connecting rod works through a flat elongated trunk, fixed to the piston and passing through a stuffing box in the bottom of the cylinder; the piston has also a round trunk projecting through the top of the cylinder, which serves as a means of lubricating the end of the connecting rod, and is made of such size that the effective area of the bottom side of the piston shall exceed the effective area of the top side of the piston by such an amount as that the weight of the piston with trunks and connecting rod complete may be correctly balanced, taking into consideration the pressure of steam intended to be used. The boiler X is of the vertical description, with a single central firebox, nearly equal in size at the bottom to the diameter of the boiler, and at the top equal to the diameter of the chimney. This boiler has been found to answer very well.

The advantages of the steam pile driving machine above described are, that the ram, piston, and rod, are made in one solid piece 10½ inches in diameter, so that there is no possibility of breaking them; and being arranged to work through both ends of the cylinders, they require no other guides; also the ends of the ram and pile are always exposed to view, and can at any time be got at without taking any of the parts to pieces. In the ordinary forms of the machine, on the other hand, the ram is made of a large square block of cast iron, secured to a small piston rod 2½ inches in diameter; this rod again has to be secured to the piston in the cylinder; and a round face has to be keyed on the end of the square metal ram to drive the pile, making in all three joints, all of which are a source of trouble by getting loose and breaking. The square metal block or ram has to be guided in a box or trunk, made of boiler plate and bolted together, so that the ram and gearing are hidden from view, as well as the end of the pile; and when anything gets wrong, the whole has to be taken to pieces, before it can be seen and remedied.

The blow from the new machine is much more effective than that of a short hammer block of the same weight, as the piston rod or ram is a bar 12 feet long weighing 35 cwt., let fall 3½ feet on end, instead of a bar 4 feet long and the same weight, let fall the same height; the blow of the long bar on end being found to be one half more effective.

Lastly, this machine drives two or more piles at the same time. It has a clear fall of 3 feet 6 inches with a weight of 35 cwt. It is carried upon the piles already driven, and does not require two extra rows of temporary piles to be driven, in order to carry it, as in ordinary machines, which, when one pile is driven, require to be shifted sideways to drive the other, besides being shifted forwards.

The CHAIRMAN enquired how long the machine had been at work, and whether it had been working continuously all the time.

Mr. BUNNING replied that it had been in constant work for nine months, during which time the whole pile driving on which it was employed had been completed. The contractor had at one time thought he should not be able to get through his contract from the very slow progress made by the hand pile driver; but by the aid of the machine he had accomplished the work much more rapidly than was expected.

The **Chairman** observed that the present machine appeared similar in action to Nasmyth's steam pile driver, except that the cylinder was now made to rest upon the pile so as to go down with it.

Mr. **Bunning** said that the action was similar, so far as regarded the use of a direct-acting steam hammer; but there was an advantage in the arrangement of the present pile driver, whereby it required no other support than the permanent piles already driven, and was capable of driving two piles at once, thus greatly expediting the work. The pile driver was a modification of the steam hammer invented by Mr. Morrison, which had been described at a previous meeting.

Mr. **Samuel Lloyd**, Jun., asked whether the stuffing box at the bottom of the cylinder would not check the blow of the hammer in falling, by the friction of so large a stuffing box.

Mr. **Bunning** replied that no difficulty of that kind had been found in practice, either in the pile driver or in the steam hammers constructed in the same manner. The stuffing box was easily adjusted so as to keep steam tight without undue friction.

Mr. **Humber** apprehended the new pile driver would be applicable only to piling cofferdams or other continuous works, and not for driving single detached piles. He enquired what was the relative cost of driving compared with the ordinary pile driving engine.

Mr. **Bunning** could not state the exact difference; but as the cost of working the present machine was little more than for an ordinary one, the greatly increased amount of work obtained would reduce the cost of driving to less than 1-20th of what it amounted to previously.

Mr. **Phillips** enquired what time was taken to drive the piles, and the nature of the ground, and what was the weight of the whole apparatus.

Mr. **Bunning** stated that the piles were driven very rapidly, 7 to 12 minutes being the time required for driving a pile to a depth of 18 to 35 feet in very difficult ground. The hammer weighed 35 cwt. in the present case, and the whole weight of the machine was about 6 or 7 tons.

The **Chairman** asked whether there were more than one of the machines at work, and whether there had been much trouble from breaking the piles.

Mr. **Bunning** replied that this was the only machine at work at present; it had been found highly satisfactory, and had never in any way damaged the piles.

Mr. Ramsbottom remarked that the blow was given entirely by the weight of the hammer, and no provision was made for admitting the steam above the piston in order to increase the force of the blow.

Mr. Bunning said that the machine might be constructed for admitting the steam above the piston for the downward stroke, and this would be necessary where the piles were to be driven in an inclined position, which was not required in the present case.

The Chairman asked whether the self-acting apparatus connected with the slide valve was always used, or whether the pile driver was worked by hand.

Mr. Bunning replied that the present machine was not made to be worked by hand, but it was intended to construct all the machines in future to be worked by hand. The steam hammers were now made to be worked by hand entirely, instead of self-acting, and it was found that 80 blows per minute could be given by hand; that plan answered practically for all purposes, and was more convenient and more readily controlled than the self-acting gearing.

Mr. Hawkes remarked that it had been found by Mr. Nasmyth that for driving piles a heavy weight falling a small height was preferable to a smaller weight falling a proportionately greater height, the effect of the blow being less injurious to the head of the pile. Atmospheric pressure had been applied by Mr. Bach, of Birmingham, for the purpose of stamping, and there appeared to be some advantages in the plan; the ram was lifted by exhausting the air from the upper part of the cylinder through a flexible tube connecting it with an air pump worked by an engine, and was then let fall by admitting the air to the top of the cylinder.

Mr. Bach thought a very simple machine might be constructed for pile driving, to be worked by atmospheric pressure, having a solid ram of cast iron instead of a piston and rod, the vacuum being produced by a small stationary or portable steam engine, which might be situated at a great distance, even a quarter of a mile, there being no loss of power from condensation in the long pipe as in the case of steam. He had found the plan work very well for stamping metals, making dish covers, and forging bolts and nuts, and could obtain 60 blows per minute by this means.

Mr. Shelley observed that Potts' pile driving machine acted on the same principle of employing air, except that the pressure of the atmosphere was made the driving power, instead of being used only to lift the ram; the air was exhausted from the interior of the piles, which were made hollow for the purpose, and piles were driven in this manner very successfully in situations where any other method might be attended with difficulties.

The CHAIRMAN said they would be glad if Mr. Bach would communicate the particulars of his apparatus, and it might lead to some further improvement in pile driving machinery. One advantage of the discussion of mechanical questions in the Institution lay in bringing the opinions of persons from different parts of the kingdom to bear upon the subject under consideration, affording an opportunity for comparing the results of experience in pursuing different objects by similar means.

Mr. BUNNING was inclined to think that even in the case of stamping it would be better to use steam power direct, instead of employing it to create a vacuum by means of an air pump, and then using the vacuum to work the machinery. There were certainly many advantages in employing air in certain cases, particularly where cleanliness of work was of importance, as in stamping medals, coining, and some other processes; but in general he thought it would be found preferable to use steam direct.

Mr. BACH observed that the use of air was attended with an advantage in all cases, in saving leakage and condensation of steam, and avoiding the complication of steam pipe joints as compared with air pipes; in pile driving operations, all the machinery worked by steam, with the boiler and fire, might be kept compact at a distance, on solid ground, and the flexible air tube could be conveyed readily to great distances without inconvenience or loss of power from cooling.

The CHAIRMAN proposed a vote of thanks to Mr. Morrison and Mr. Bunning, which was passed.

The Meeting then terminated; and after the meeting, Mr. Follett Osler, of Birmingham, exhibited a gyroscope of large size, for the purpose of illustrating the stability of the axis of rotation of a revolving body. A new steam pressure gauge was also exhibited, by Mr. John Inshaw, of Birmingham.

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